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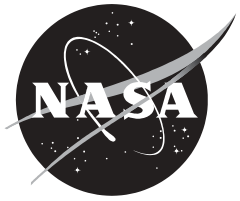

Virtual Airspace Modeling and Simulation (VAMS) Project
Second Technical Interchange Meeting

Prepared by Computer Sciences Corporation
Recording Secretaries:
Larry Babb
Robert Beard
Richard Kirsten
Jay Pollock
Paul Rigterink

Edited by: Melinda F. Gratteau, Raytheon ITSS

Proceedings of a technical interchange meeting
sponsored by the
National Aeronautics and Space Administration
and held at
NASA Ames Research Center
Moffett Field, California
August 27-28, 2002

November 2002

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Virtual Modeling and Simulation (VAMS) Project
Technical Interchange Meeting Number 2
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Preface

A two-day NASA Virtual Airspace and Modeling Project (VAMS) Technical Interchange Meeting (TIM) was held at the NASA Ames Research Center in Mountain View, CA, on August 27 and August 28, 2002. The purpose of this meeting was to share information about the early modeling and simulation activities and how they relate to advance air transportation system concepts sponsored by the VAMS Project. The overall goal of the VAMS Project is to develop validated, blended, robust, and transition-able air transportation system concepts over the next five years that will achieve NASA's long-term Enterprise Aviation Capacity goals. This document describes the presentations at the TIM and their related questions and answers, and presents the TIM recommendations.

The objectives TIM 2 were to continue the information exchange with VAMS participants, describe the VAST requirements definition process, define and begin to address the current VAST challenges, report VAST definition and development status, and continue development of scenario and metric definitions.

Three simultaneous breakout sessions were conducted to provide comments on five scenario/metric parameter categories and the individual items which make up those categories. The notes from the three breakout sessions are contained in Section 5 – Breakout: Scenario and Metrics. Ms. Sandra Lozito's summary and synthesis of the three breakout sessions is contained in Section 6 – Report on Breakout Sessions.

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Agenda

PST	27-Aug Tuesday	28-Aug Wednesday
7:30	Facility opens and Meeting Registration	Facility opens
7:45		
8:00		Daily Agenda
8:15		VAST Non-Real-Time (Roth) Overview (Sweet) Models (Hunter) Data (Sweet) Validation (Abramson)
8:30	NASA Greeting (Swenson)	
8:45	TIM #2 Overview (Romer)	
9:00	ATS Traffic Demand Modeling (Cavolowsky)	
9:15		
9:30	Scenarios and Metrics (Lozito)	
9:45		
10:00	Break	Break
10:15		
10:30	Breakout **Scenarios and Metrics** (3 separate parallel sessions)	VAST Non-Real-Time (cont.)
10:45		
11:00		
11:15		Real-Time Validation Experiment (Lozito)
11:30		
11:45		Catered Lunch in Patio Room
Noon	Catered Lunch in Patio Room	
12:15		
12:30		
12:45		
1:00		VAST Real-Time (Malsom)
1:15	Concept Modeling Requirements (Tobias)	
1:30		
1:45	Concept Portrayal Response (James)	
2:00		
2:15		
2:30	Report on Breakout	
2:45		Break
3:00	Break	
3:15		Human/Team Modeling (Remington)
3:30	VAST Requirements (Romer)	
3:45		
4:00		CNS Modeling (Mainger)
4:15		
4:30	System Analyis Tools (Dollyhigh & Millsaps)	
4:45		Next Step and Preview of TIM #3
5:00	Wrap-up	

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1.
NASA Greeting to the Virtual Airspace Modeling and Simulation (VAMS) Project Second Technical Interchange Meeting (TIM 2)

Mr. Harry Swenson
Project Manager, Virtual Airspace Modeling and Simulation (VAMS)
NASA Ames Research Center

A copy of Mr. Swenson's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. Swenson

VAMS Project Vision, Technical Objectives, and Technical Approach (Slides 1 – 4)

Under the VAMS Project, NASA is developing a revolutionary vision for a seamless, safe, and secure Air Transportation System that requires the development and analysis of paradigm shifting operational concepts and technologies. This will promote future economic growth through significant increases in the movement of goods and people in a cost-effective fashion. The VAMS Project vision has not changed since TIM 1. TIM 2 will help coordinate the overlap of the three main technical objectives (develop modeling and simulation tools, create evaluation methods and techniques, and develop operational concepts). The VAMS technical objectives also have not changed since TIM 1. The tradeoffs made in achieving VAMS technical objectives gives the project definition.

The VAMS technical approach will use a significant amount of existing models to the extent that funding allows and as needed to evaluate and assess revolutionary operational concepts. Improved models will be developed and validated with a baseline set of information and used to create project deliverables and assess operational concepts.

VAMS Roadmap and Status (Slides 5 – 6)

The VAMS Project is on schedule and deliverables will be sent to NASA Headquarters on time. Operational concepts have been identified and preliminary definitions and scenarios have been prepared. A prototype modeling toolbox, called Aerospace Concept Evaluation System (ACES), has been developed. In addition, the initial real-time (RT) simulation has been defined and a preliminary design review of the initial RT simulation has been conducted. The ACES Build 1 Non-Real-Time (NRT) system and the development of a common scenario set are on schedule. NASA Ames received a new request from NASA Headquarters that the VAMS project advance at least one concept using the ACES Build 1 Non-Real-time system earlier than scheduled. This work is on schedule.

TIM 2 participants were urged to leverage concepts and share information.

Synopsis of Questions and Answers for Mr. Swenson

After the presentation, Mr. Swenson responded to questions from TIM participants as follows:

- What is the process for integrating concepts?

  The TIM participants are asked to:

  - Use a common view of the architecture.
  - Define concepts in a way that can be modeled.
  - Follow the NRA instructions so that the concept information can be blended.

  Integrating concepts is a hard problem. The concept definition must be concrete and detailed definitions (including interfaces) must be given.

2.
Technical Interchange Meeting #2 Overview

Mr. Tom Romer
Level 3 Lead, Virtual Airspace Modeling and Simulation Technologies (VAST)
NASA Ames Research Center

A copy Mr. Romer's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Mr. Romer introduced the TIM's objectives, agenda, and logistics.

Key Comments by Mr. Romer

TIM #2 Objectives (Slide 3)

The objectives of the TIM are to continue the information exchange with VAMS participants, describe the VAST requirements definition process, define and begin to address the current VAST challenges, report VAST definition and development status, and continue development of scenario and metric definitions.

Agenda (Slide 4)

This slide contains a detailed agenda for each day of the TIM: Tuesday August 27, 2002 and Wednesday August 28, 2002. While the agenda has defined times, some flexibility will necessarily be accommodated.

Logistics (Slide 5)

Phone messages can be left with conference center staff and Macintosh computers and hookups for laptops are available. Refreshments are also available for those who have paid a conference fee. Breakout sessions will be held in the Patio, North Wing, and Ballroom areas.

TIM #2 Content (Slide 6)

The VAST requirements definition process will cover demand forecasting and modeling, scenarios and metrics development, and VAMS concept modeling and simulation.

The TIM will address the necessary synergy with other modeling and simulation efforts.

The TIM will also address definition and the current status of development efforts.

3.
Socio-Economic and Demand Forecasting

Dr. John A. Cavolowsky
Assistant Director, Airspace Systems Program
NASA Ames Research Center

A copy of Dr. Cavolowsky's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Dr. Cavolowsky

High-Level View (Slides 1 – 3)

The activity is jointly funded by the VAMS Project and the Airspace Systems Program Office. This presentation has strong, direct ties to Sandra Lozito's Systems Evaluation and Assessment (SEA) presentation.

A combination of economics and demand drives public and private investment decisions. This effort can lead to program-level investment analysis.

The VAMS objective must necessarily and critically consider the national and global economic environment in which the technologies operate. The VAMS problem definition is limited to air travel, but multi-modal considerations are part of the economic environment.

Study Approach (Slide 4)

The study focus will be developing an understanding of the role transportation in general and air transportation in particular within the U.S. economy, the major determinants of air traffic demand, and how an intermodal perspective may affect our understanding of air travel demand.

National and global economic scenarios, the focus of the activity, operate above VAMS' air traffic management scenarios. These higher-level scenarios help define operational-level scenarios reflecting future environments and will include demographic, economic, security, airport/airspace capacity, and global political considerations.

Supporting Organizations (Slide 5)

Logistics Management Institute (LMI), Gellman Research Associates (GRA), Volpe National Transportation Systems Center, affiliated consultants, and universities provide important knowledge and expertise.

The next 6 months involve a four-part activity.

1. Understand the current state of knowledge through a combination of literature search and examination of use by economic sector to determine mode choice and economic impact.
2. Review existing models to document strengths and weaknesses.
3. Develop a demand forecast by economic sector.
4. Develop a "schedule" of demand.

The Future Is Uncertain (Slides 6 – 7)

Technology lead times may be extremely long and conditions are likely to change, but we must press on.

- Identify driving forces and their potential range of variation.

- Create broadly based scenarios that cover the range of drivers.
- Scenarios will be developed and then a few (only a handful) will be studied in detail to show system trends, evaluate costs, and assess risk.

Resources are limited and they must be allocated to areas likely to achieve net benefit with a high probability of being realized. The use of "likely" and "high probability" means that any single chosen scenario might be useless. This activity starts with a "National Research Council assessment" focusing on four to six scenarios and the 20-year horizon, which too soon limits the impact and much later has higher risk due to uncertainty. The scenarios need to be "orthogonal" (at large angles) to maximize their benefit.

The demand forecasts; developed with data from Boeing, Airbus, FAA, and the International Civil Aviation Organization (ICAO); will be by market segment, e.g., regional versus mainline carriers, cargo general aviation, fixed wing and rotorcraft, and different sizes of aircraft.

The Activity Is a Three-Part Effort (Slides 8 – 19)

1. There is a literature search and an analysis of passenger and cargo use by economic sector. Then, the study will look at past studies and existing models, assessing their strengths and weaknesses and deriving measures that "appeal" to technical audiences and "lay" audiences.
2. The bulk of the effort:

   Review forecasts — ask what the smart people are saying. A difficulty is that forecasts range in scope and duration, e.g., 10 to 50 years.

   Develop market segments of interest — the forecasts have to deal with all market segments, i.e., regional, mainline, General Aviation (GA), cargo, and other modes.

   Identify demand drivers — access, travel times, travel costs, and attractiveness of other modes.

   Identify supply issues — travel times, travel costs, security costs, fuel prices, air navigation, and airport charges.

   Align demand with scenarios—This must be done by market segment and address all scenario issues for each scenario. The activity must include the "full cost" of the travel to enable mode tradeoffs on the demand side. "Orthogonal" alignment of demands and issues is required.

   Produce input to activity 3.
3. Generate demand forecasts in the aggregate and for airport pairs that lead to a traffic schedule profile for each scenario using the three axes of interest.
   i. Low volume versus high volume.
   ii. Scheduled versus demand — this provides insight into the ability to satisfy the customers' time demands.
   iii. Hub and spoke versus point-to-point — this provides insight into the ability to satisfy the customers' place demands.

Traffic patterns for each scenario will include time-of-day profiles and address commercial and general aviation traffic. General aviation traffic models are based on Small Aircraft Transportation System (SATS) work done previously as well as current work.

Follow-on (Slide 20)

Identify items affecting aviation system and inhibitors (social and economic), and work with the Systems Evaluation and Assessment sub-element (SEA) activity to help identify metrics and supply data.

Synopsis of Questions and Answers for Dr. Cavolowsky

After the presentation, Dr. Cavolowsky responded to questions from TIM participants as follows:

- Does this activity consider door-to-door instead of gate-to-gate?

  It must necessarily look beyond air only. The Logistics Management Institute has Small Aircraft Transportation System data that relates to door-to-door models mostly for regional airports.

- Are you considering the infrastructure necessary to implement the scenarios?

  While there is some overlap with and linkage to the metrics and measures of the SEA sub-element activity, this activity addresses infrastructure with neither equivalent breadth nor depth.

- What pool of airports is being used for airport pairs?

  LMI is the primary link. A "106" airport model is being used with the intent of going to 800 airports.

  Shahab Hasan, (LMI), answered that the 108 airports are primarily mainline and regional carriers while 3,000 airports will be ultimately used to support general aviation and Small Air Transportation System models.

- What constitutes a day's demand? Is this a year 2022 day or a range of days?

  A single day's demand is extrapolated into the future from a "composite day" in the present. This single day's demand is used to estimate yearly impact.

- Are you able to establish certainty bands for scenarios "most likely to provide benefit"? Where are the 95 percent certainty bands?

  No, the nature of this work does not lend itself to numerical certainty bands (e.g., 95 percent confidence level). The team has struggled with the issue of numerical certainty bands and decided that a set of scenarios selected by the "likely to benefit" criterion is the correct approach.

4.
Systems Evaluation and Assessment (SEA) Sub-Element

Ms. Sandy Lozito
Level 3 Manager, Systems Evaluation and Assessment (SEA)
NASA Ames Research Center

A copy of Ms. Lozito's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Ms. Lozito

VAMS Sub-Elements Relationships (Slide 2)

The Systems Evaluation and Assessment (SEA) sub-element is new to the VAMS project. The role of the SEA sub-element is to develop the methods and metrics that the VAMS project will use for evaluation of concepts. The SEA sub-element is interdependent on the System-Level Integrated Concepts (SLIC) sub-element and the Virtual Airspace Simulation Technologies (VAST) sub-element. SEA will provide scenarios and metrics requirements to VAST, which will develop the models for use in concept evaluation. SEA will also provide strategies for testing to the SLIC sub-element. The SLIC sub-element will then provide the developed concepts to SEA for evaluation. SEA will conduct the assessment and evaluation of the selected concepts.

The SEA sub-element also has a relationship with the concept developers. The concept developers will conduct a self-assessment of their concepts using their own scenarios and metrics. The self-assessment metrics and scenarios will be provided to the SEA sub-element for use in the overall definition of scenario and metric requirements.

SEA General Tasks (Slide 3)

The SEA sub-element will be responsible for developing the requirements for the scenarios and metrics that will drive the real-time tools created by the VAST sub-element. After these tools are developed by VAST, the SEA sub-element will conduct an evaluation assessment on the tools.

The SEA sub-element will then use the VAST tools to conduct an initial assessment of the concepts submitted to VAMS. An integrated or blended set of concepts is planned for Phase 4 of VAMS. The SEA sub-element will use the VAST tools to conduct an initial assessment of this integrated set of concepts as well as the final evaluation of the selected concepts.

Scenario Metric/Requirements (Slides 4 - 5)

A common or standard set of scenarios and metrics will be developed and used to evaluate the capacity-increasing concepts of the VAMS project. The SEA sub-element will be responsible for defining the requirements of this standard set of scenarios and metrics. The starting point for the definition of the VAMS scenarios and metrics will come from the concept developers themselves. Each concept will be required to conduct a self-assessment using a set of scenarios and metrics. These scenarios and metrics will be provided to the SEA sub-element for use in defining and developing the VAMS scenarios and metrics.

VAMS will require many scenarios and metrics but ultimately they must be applicable for broad evaluations for all the concepts that will be evaluated. The starting point for the definition of the scenarios was summarized during the presentation. Scenarios must test the ability to increase capacity and maintain or increase safety. Scenarios must cover all combinations of domains of operations. Scenarios must consider normal and non-normal events. Non-normal events will include human performance

evaluations. Scenarios must include real-time and fast-time (non-real-time) capabilities. Scenarios must include all users of the NAS. This includes AOC, ATC, and the aircraft.

SEA Scenario Parameters (Slides 6 –7)

The SEA sub-element has established five general categories or scenario parameters to capture the model areas. These categories include Forecast, Demand, System, Environment, and Scope. Each scenario parameter will consist of a number of attributes. These attributes as well as the category parameters are the subject of the Breakout session of this TIM. The SEA sub-element will be looking for inputs and comments from the VAMS participants on the scenario parameters and attributes. The inputs and comments will be the subject of the Breakout Session Report.

SEA Scenario Derivation Process (Slide 8)

The framework for scenario and metrics development was presented in Slide 8. It represents a structured process that will be used by the SEA sub-element. In addition, there will be other processes that will be evaluated by the SEA sub-element as they mature.

Synopsis of Questions and Answers for Ms. Lozito

After the presentation, Ms. Lozito responded to questions and comments from TIM participants as follows:

- Is SEA going to consider low-fidelity-type cognitive walkthroughs or any other techniques or is it going to focus on scenarios and metrics for real-time and fast-time?

  Empirical analysis and analytical approaches might exist but SEA intends to let the concept developers and requirements define what will be used to evaluate the concepts.

- How can War and Pestilence be incorporated in scenarios and be validated with testing?

  It is recognized that there is a need to recognize war and pestilence-like situations but the SEA sub-element does not know how to do that yet. It is possible that empirical analysis can determine a "demand" parameter effect that might be modeled. As the models are used, better representation may then be developed or provided.

- What is the baseline date for data to be used?

  Right now the baseline date is the 1997 data. However, a later date may be selected if data are available.

- Are concept developers going to be able to select particular "days" or type of scenario data to use as the baseline for all capacity-increasing concepts to use? When is this going to happen?

  The intent is to have a common baseline and a common "perturbation" for all concept developers to use. Comparisons must be available against standard data.

- Does the matrix of categories apply to just the year 2020 or are there separate stages or phases of the future?

  No decision has been made yet.

- Comment: Availability of data for the selected baseline year is critical.

5.
Breakout – Scenarios and Metrics

Facilitators: Sandra Lozito, Lynne Martin, Savita Velma
Human Factors Research and Technology Division
NASA Ames Research Center

For the Breakout Sessions, the workshop participants were divided into three groups. Each group was asked to provide comments on the five scenario/metric parameters:

1. Forecast (economic activity, energy availability, war and pestilence, environmental concerns, demographics, travel confidence)
2. Demand (number of airports, fleet mix, load factor, schedule, origin/destination pair)
3. System (aircraft characteristics, airport characteristics, airspace characteristics, Communications, Navigation and Surveillance (CNS) infrastructure, National Airspace System (NAS) architecture, humans)
4. Environment (weather, safety situations, failures, security situations)
5. Scope (whole versus part of NAS, fidelity of the scenario, temporal resolution, simulation timing/synchronization)

Slides prepared during the Breakout Sessions in response were summarized by Ms. Lozito in a subsequent presentation and are available on the Web at http://www.asc.nasa.gov/vams/.

5.1 Breakout Session 1

Key Comments During Breakout Session 1

Key comments on the five scenario/metric parameters are given below:

1. Forecast

- The forecast drives the expected demand.
- A forecast may not need to be modeled.
- Forecast is a preliminary process in determining demand.
- Forecast gives justification for the expected demand.
- Could rename "forecast" heading to "context or factors influencing demand."
- Need to differentiate between demand and operational scenarios.
- Cannot assume how airlines will run business in future.
- Need to consider special situations such as loss of a major airport due to a hurricane.

2. Demand

- Demand includes passenger, general aviation, and cargo demand.
- Demand includes how do you want to get there (choice of transportation mode).
- Flow demand (city-to-city demand).
- Need to simulate levels of demand.
- Need to specify transportation resources needed.

- Need to differentiate between demand and operational scenarios.
- Need to add airport operating time, organizational affiliation, etc.

3. **System** — In addition to what is listed, the system includes the following:
   - Airlines configuration
   - Taxiway configuration(s)
   - A/C performance
   - Fuel type
   - Aircraft type (fleet mix)

   Need to describe transient effects that affect system.

   For airports, we need to describe:
   - Number of runways and runway length
   - Parallel approaches
   - Takeoff and landing performance based on conditions

   For airspace, we need to describe:
   - Current versus new configurations (i.e., sectors or sector-less)
   - Restricted versus unrestricted
   - Structure definition

   For CNS, we need to describe:
   - Delays and throughput
   - Link performance (delay and throughput)
   - System loading
   - Tactical versus strategic capability
   - CNS required capability versus what is available

   For NAS Architecture, if we need this, we need to:
   - Specify algorithms
   - Start with fast simulation and then go to more detail
   - Identify critical behavior
   - Reduced Vertical Separation Model (RVSM)

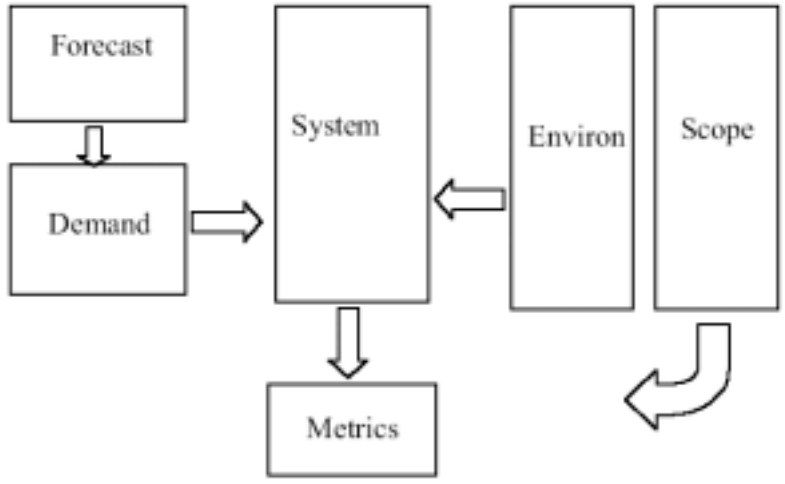
4. **Environment** — In addition to what is listed, the environment includes:
   - Weather effects on runway (wake vortex, usability of runway)
   - Uncertainty of events
   - Blunders
   - Security delays (recovery of security events) as well as facility closures

5. **Scope** — Participants discussed if we need to model entire NAS or just behavior of NAS (Air Traffic Management or ATM/CNS portions). They suggested that we model:
    - Multiple days
    - Triad of players (flight deck, ATM, Airlines Operations Center or AOC)

5.2 Breakout Session 2

Key Comments During the Breakout Session by Participants in Workgroup No. 2

- "Category" discussion questions
    - Is the list of "primitives" complete?
    - Is the list to long?
    - What is the cause/affect relationship between primitives across categories?
    - How do categories relate into each other?
    - "Level" of primitives need to be reviewed to ensure all concepts can be evaluated
- The following figure, ultimately included in Ms. Lozito's summary of the breakout sessions shows one relationship between the categories.



- Make the following category changes:
    - Forecast ⇒ Forecast Assumptions.
    - Demand ⇒ Unconstrained Demand.
    - Environment ⇒ System Limitations/Constraints.
- Make the following primitive changes:
    - Environment Concerns ⇒ Environment Policy.
    - Include "Passenger/Cargo " primitive in a category (replacing load factor?).
    - Remove "schedule" from primitive list.
- Some changes to category scope are needed.
    - There is a need to deal with a range versus a single average scenario. The behavior within the range is non-linear.

- The time stamp must be set through metrics/objectives – batching both fast-time and real-time simulations.

- Items from the 'white board'.
  - Nominal scenario (capacity) needs off-nominal considerations.
  - What "challenge" events are relevant for the scenarios?
  - Validity of elements in more than one place.
  - Forecast limits capacity.
  - Demand
    - Passenger load is the fundamental load.
    - Has to also capture general aviation and unscheduled flights
    - Load must be a composite of passenger and cargo traffic
  - Specify event by action, not by name; e.g., shutdown, not 9/11.
  - Specify only input parameters.
  - Schedules must be driven by the concept.
  - There is a need for a consistent set of definitions.
  - Study has to support the overall project objectives.
  - What should developers consider in their baseline scenarios and metrics? The currently undefined nature of system scenarios and baselines is an issue for the concept developers.
  - It is not clear what CNS capabilities need to be represented in scenarios.
  - How long do the scenarios need to be to reflect realism for each concept? Long means some currently unknown combination of size, complexity, fidelity, and scope.
  - What are the technical challenges in scenario development?
  - How do we ensure the appropriate testing of the concepts that include only one domain versus those that are gate-to-gate?
  - Since we have multiple scenarios, how do we ensure enough comparability between them so that we can fairly test single domain versus gate-to-gate concepts?

5.3 Breakout Session 3

Key Comments During the Breakout Session by Participants in Workgroup No. 3

- Focus — Passenger focus (door-to-door) is program or project level. VAMS focuses on gate-to-gate. VAMS feeds upward into door-to-door level model.
- How does international traffic impact hubs? There are significant traffic volumes at some airports, e.g., 15 percent at Los Angeles International (LAX). Ignoring it gives skewed answers.
- War and Pestilence
  - Does it reduce overall traffic? Military carriers may be up, especially U.S.-initiated international flights.
  - September 11 added dynamic, restricted airspace.
  - These are shocks to the "normal" situation. Feel that "shocks" have to be addressed. How big are the shocks; e.g., September 11 total shutdown? Feeling is that September 11 is out of scope, but still TBD.

- Identify driving forces and their potential range of variation.

- Normal versus abnormal — concern that out-of-normal may overwhelm scenario mix.
  - Will individual modelers have to account for all common scenarios and factors or will they get to choose Chinese-menu style (risky)?
  - How frequent and how long? There is some past data, e.g., flights out of Travis for military action in Afghanistan.
  - Frequency is important.
  - We won't be making up data where it doesn't exist.
  - Abnormal situations are harder to validate. Data exist for bad whether in the summertime. Data doesn't exist for many of the shock factors.
  - But leaving it to the end may result in many "unanswered questions."
- Weather has data and highest frequency. It's the "normal/abnormal" situation.
  - Need good weather models — global and airport specific.
  - Good data are key.
  - Scenarios and simulation must capture these.
- "Rare normal" events — Maybe an inexact "impact assessment" may have value before a metric is available.
  - Stressors determine where concepts will "break." Even if the specifics aren't right, the trend and the learning will likely provide info.
  - Step function/impulse response.
- Primary stakeholders—NASA, FAA, OMB — drive the prioritization.
- Scenario — What constitutes it, how do we create it, how do we measure it?
  - Storyboard approach — same process for all scenarios — has worked in one environment. Same process helps consistency.
  - Working on what will be delivered — requirements and storyboard—for both non-real-time and real-time.
    - Coming up, hopefully shortly after the TIM.
  - Government policy (e.g., 100 percent X-ray) may impact scenarios.
    - Maybe specifics appear in each of the five categories.
- Metrics and deliverables — Apples to apples may not be possible given the wide range of concepts and their relative maturities. A completely level playing field may not be possible.
  - Answer — If it can't demonstrate capacity increase, it's out.
- Scenarios and metrics are to evaluate concepts, not particular technologies or models.
  - Simulation, at a lower level, is plug-and-play.
  - Data, looks like a lot, but the list of archived items is "short." The data set is bounded, but voluminous. But a lot of information is never recorded = unavailable.
    - John's activity will be providing/setting up data sources that will be shared with the community.
    - Everybody needs to be on the "same data page." Are there some other things out there that we don't all know about?

- Self-evaluation will help data definition to evolve—Larger set of folk coming up with ideas enhances variability.

- Capacity-limiting bumpers need to be considered (e.g., wake-vortex separation, runways) as bounds to the models.
  - Some already exist.
- SEA provides the definition of the scenarios (inputs, outputs, considerations) to the VAST sub-element to ensure tool evaluation is good and back to the concept developers to tweak/enrich the concept set.
  - Parameter list is growing. It will be weeded/collapsed in the future.
- How do the data create the world of the future?
- Common terminology is important—Project Office has developed and will distribute a lexicon.
- Airline proprietary data:
  - Wait until it becomes an issue then attack it.
  - "Genericize" it for use in scenarios.
- Document the faults and limitations of each of the data sets. If this is not done, then the analysis will be compromised.
- Passengers are taxpayers (owners).
- Consensus is that human factors should not be a separate category.
  - Humans provide both key capabilities and key limitations to the system and must be part of the system.
    - It's not likely that approaches to "engineer the humans out" will be affordable, or reasonable because humans provide the veto power.
    - The system can enhance human strengths and overcome limitations.
  - Both need to be reflected in the scenarios and models.
  - Quantifying human factors is harder and less well defined than doing it for "wing loading," but …
  - There are "critical paths" to action activities that can be modeled.
  - Remember that humans "change the task" when they become overworked. Don't tackle a concept that is impossible for humans to use.
- How do we address technology change in the system category?
  - The cycles are getting shorter in the marketplace.
  - There are automation and training.
- The 20-year forecast is in the Program Office. Are we going to develop scenarios for intermediate points, e.g., 10 and 15 years, too?
- Common scenarios are coming from VAST.
  - Individual activities will provide building block scenarios for the common scenarios (to be distributed back to the individual activities) and used in a "kludged format."

6.
Report on Breakout Sessions

Ms. Sandra Lozito
Level 3 Lead, Systems Evaluation and Assessment (SEA)
NASA Ames Research Center

A copy of Ms. Lozito's summary of the breakout sessions is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Ms. Lozito's summary is an extraction and combination of information from the three breakout sessions. As such, it duplicates much of information in Section 5 – Breakout: Scenarios and Metrics.

For presentation purposes, the report of the breakout section follows the reports from the individual sessions instead of being located in its natural chronological sequence.

Key Comments by Ms. Lozito

The Systems Evaluation and Assessment (SEA) sub-element has established five general scenario categories capture the model requirements including: Forecast, Demand, System, Environment and Scope. Each category contains a set of parameters. These parameters as well as the categories were the subject of the Breakout session. VAMS TIM 2 participants were asked for their inputs and comments on the scenario parameters and categories.

Questions Presented from Breakout Session

The following questions were summarized from the breakout session.

- How does the data create the world of the future? There are concerns that the existing databases for the models do not address future conditions.
- Should Virtual Airspace Simulation Technologies (VAST) contain the actual system such as datalink or a model that represents the functional performance of the system?
- When should a concept use the fast scenario and when should the concept use the real-time scenario?
- To what extent is passenger focus (door-to-door) a program level or project level? VAMS focuses on gate-to-gate. VAMS feeds upward into door-to-door level model.
- How does international traffic impact the scenario development? There are significant traffic volumes at some airports. Ignoring it will give skewed answers.
- How do we handle the possible mismatch between the concepts and the evolving National Airspace System (NAS) tools?
- Many questions were asked relating to the War and Pestilence attribute. Does it reduce overall traffic? How big are shock events? Answers to these and others are still unknown.
- How should technology changes be addressed in the system category? Cycles are getting shorted in the market place. There are automation and training issues.
- Is VAMS going to develop scenarios for intermediate points (e.g., 10- and 15-year points) of the 20-year forecast? There was considerable interest and discussion about this in the breakout sessions, but no decision has been made.
- One of the groups restructured the categories (see last slide of the presentation) into what they felt flowed:

- Economic forecast is first.
- Demand is driven by forecast.
- The combination of demand and environment (e.g., security) drives the system.
- The system has the architecture, the infrastructure, and the airports and produces metrics.
- Scope is an outlier category containing methods and decisions (e.g., all or part of NAS).

Open-Ended Discussion Issues from Breakout Session

Some discussion areas could not be summarized as questions or comments.

- Normal versus abnormal: there is concern that out-of-normal may overwhelm the scenario mix.
  - Will individual modelers have to account for all common scenarios and factors or will they get to choose Chinese-menu style (risky)?
  - How frequent and how long?
    - Frequency is important.
    - We won't be making up data where it doesn't exist.
  - Abnormal situations are harder to validate. Data exists for bad whether in the summertime. Data doesn't exist for many of the shock factors.
  - Leaving it (abnormal situations) to the end may result in many "unanswered questions."
  - Weather has data and highest frequency. It's the "normal/abnormal" situation.
- Airline proprietary data.
  - Wait until it becomes an issue and then attack it.
  - "Genericize" it for use in scenarios.
- The consensus is that human factors should not be a separate category.
  - Humans provide both key capabilities and key limitations to the system and must be part of the system. If a separate category and not part of the system, there is risk that it would be "left out." Human factors have to be included early.
  - Both capabilities and limitations need to be reflected in the scenarios and models.
  - Remember that humans "change the task" when they become overworked. Do not tackle a concept that is impossible for humans to use.

Synopsis of Questions and Answers for Ms. Lozito

After the presentation, Ms. Lozito responded to questions and comments from TIM participants as follows:

- **Comment:** A breakout session comment was missing from the presentation. "Researchers need understanding of Airline Operations Center (AOC) and facilities. Researchers need to get into those facilities and understand what is really needed. A responsible researcher should understand the subject area before any analysis can be performed."
- **Comment:** It is important for concept developers to understand the capacity comparisons when starting to define the baseline by which they will be measured.

7.
Development of Modeling and Simulation Capability Driven by Concepts

Dr. Len Tobias
Terminal Area ATM Research Branch
NASA Ames Research Center

A copy of Dr. Tobias' presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Dr. Tobias

Introduction (Slides 1 – 4)

The information provided by the NASA Research Announcement (NRA) participants (including their proposals, TIM 1 charts, and conversations with NASA Technical monitors) is being reviewed to determine the most effective means of letting the concepts drive the modeling and simulation capability development. It is expected that after the NASA review of the concepts is complete, NASA will have a better idea of the concepts, concept validation needs, concept integration, and the Virtual Airspace Modeling and Simulation Technologies (VAST) modeling and simulation framework, as well as the issues that must be resolved. Then, given the issues, time, staff, and dollars available, NASA will make decisions on how to proceed and will refine their guidelines for selecting what to address.

Summary of Concepts (Slides 5 – 13)

A summary of the four system-level and five domain-specific concepts is given in Slides 5-13 from the perspective of the NASA reviewers. This material was presented as an introduction for NASA's ideas on (1) what modeling and simulation need to address, (2) the issues for simulating capacity concepts, and (3) their suggested guidelines for how to use concepts to drive the modeling and simulation development. The NRA concept developers were given a chance to respond to NASA's portrayal of their concepts as well as the issues and guidelines that were presented during the following presentation by Mr. Kevin James.

What Modeling and Simulation Need to Address and Issues for Simulating Capacity Concepts (Slides 14 – 18)

Modeling and simulation need to address the existing Air Traffic Management (ATM) framework, ATM innovations, and their impacts of safety, security, and the environment. General issues and evaluation issues were addressed. General issues include the following:

1. The importance of providing adequate specificity for a capacity-improving concept.
2. The need to know how much a particular concept will improve capacity.
3. The issues with a concept.
4. The capacity that a concept can realistically achieve.
5. The need for a concept to be cost-effective.

Evaluation issues include the following:

1. Identification of the best method for evaluating system-wide concepts versus domain specific concepts.
2. The selection of what to simulate.

3. The design of the simulation environment.
4. The need for concepts to interact with each other and with the simulation environment.
5. Specific evaluation issues such as “Do we need a pseudo pilot for surface concept evaluation.”

Error analysis is expected to be a challenge.

Suggested Guidelines on How to Use Concepts to Drive the Modeling and Simulation Development (Slide 19)

The suggested guidelines for using concepts to drive the modeling and simulation development are shown in Slide 19. The focus on errors, deviations, and abnormalities will ensure a complete evaluation. It was suggested that they initially evaluate and compare two surface or two terminal domain-specific concepts. In addition, it was noted that the weather concept would be an easier concept to test the integration process of two concepts.

Synopsis of Questions and Answers for Dr. Tobias

There were no questions for Dr. Tobias from TIM participants.

8.
Concept Portrayal Response: The Developer's Turn

Mr. Kevin James
Airspace Operations Modeling Office
NASA Ames Research Center

A copy of Mr. James' presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. James

Mr. James reiterated that the purpose of TIM 2 is to exchange information, particularly that about the concepts. The individual presenters then took a few minutes each to extemporaneously summarize their concepts and the requirements their concepts placed on the Virtual Airspace Modeling and Simulation Technologies. Their requirements are summarized in the following table.

VAST Requirements from Concept Developers

Concept developers spoke extemporaneously; briefly summarizing their concepts and the requirements those concepts would place on the VAST system.

Copies of three presentations (Raytheon C^3I, Seagull Technology and Metron Aviation) given in writing are attached as a part of the appendix and are available on the Web at http://www.asc.nasa.gov/vams/.

There were no questions for any presenter.

Concept Level	Concept Name	Speaker	VAST Requirements Identified
System	All-Weather Maximum Capacity Concept	Dr. Jimmy Krozel Metron Aviation	• Capability to dynamically adjust jet route definitions to increase capacity • To get around weather, a "free-flight" (FF) type concept is required • This concept wants to ensure that other concept developers include - Weather in scenarios & metrics - Scenarios need to include situations where actual weather does not agree with forecasted weather
System	Massive Point-to-Point and On-Demand	Mr. Brian Kiger Seagull Technology	• Multi-modal modeling • A cost model for multi-model evaluation • Representation of 5,400 airports including cost models • Conflict-free (between aircraft, weather, and wake vortices) 4-D precision trajectories • Airline Operations Center (AOC) precision control toolboxes • Dynamic Air Route Traffic Control Centers (ARTCCs) and sectorless flight levels • Self-separation of aircraft • Mixed equipage in the aircraft models and in the scenarios which use them • Communication, Navigation and Surveillance (CNS) models

Concept Level	Concept Name	Speaker	VAST Requirements Identified
System	Air Transportation System Capacity-Increasing Concepts Research Proposal	Mr. Alvin Sipe Boeing	• An integrated planning base in each sector • Ability to predict position • Ability to estimate and bound the errors in position prediction
System	Capacity Improvements Through Automated Surface Traffic Control	Dr. Brian Capozzi Metron Aviation	• Model the details on the surface • Human-in-the-loop (HITL) capabilities • The processes that occur inside the ramp tower • Ability to address human factors issues; e.g., Pilot work load
Domain Specific	Surface Operations Automation Research	Dr. Victor H. L. Cheng, Optimal Synthesis, Inc	• Simulation of surface traffic (possibly with a human in the loop). • High fidelity tower and flight deck mockups with humans in the loop
Domain Specific	Centralized Terminal Operation	Mr. John Fergus Northrop Grumman Information Technologies	• Agreed upon performance baseline • Documented interfaces • Documented VAST requirements specifying operating system and programming languages • Model list which includes the model source and fidelity information
Domain Specific	Terminal Area Capacity Enhancement	Ms. Mary Miller Raytheon	• Guidance about the functions and level(s) of fidelity needed • Models of enabling CNS technologies; e.g., WAAS and ADS-B. • Capability to include realistic errors for FMS, navigation tracking, and surveillance/communication in the models and scenarios • Ability to select model input & to drive models parametrically • Wake vortex model • Weather model(s)
Domain Specific	Advanced Airspace Concept (En Route)	Mr. Russ Paielli NASA	• No additional modeling capabilities are required. Aircraft must have upgrade equipage for the concept to work.

9.
VAST Requirements

Tom Romer
Level 3 Lead, Virtual Airspace Modeling and Simulation Technologies (VAST)
NASA Ames Research Center

A copy of Mr. Romer's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. Romer

Introduction (Slides 1 – 2)

The purpose of this presentation was to describe the Virtual Airspace Modeling and Simulation Technologies (VAST) requirements definition process, the requirements approach, the VAMS deliverables, and the challenges that need to be addressed in meeting VAST requirements.

Requirements Definition Process (Slides 3 – 4)

The VAST requirements team is receiving requirements from all sub-elements of the project including the System Evaluation and Assessment (SEA), System-Level Integrated Concepts (SLIC), and VAST organizations. The functional responsibility of these organizations in the requirements definition process is shown in Slide 3. The requirements are then mapped to the concept functional model (see Slide 8). A simplified requirements flow (without feedback loops) is shown in Slide 4. Note that having a thorough understanding of the metrics early is important for the requirements development process.

Requirements Approach (Slides 5 - 10)

The phasing of the project does not allow a perfect-world requirements definition process. In particular, some of the consequences of the lack of a perfect world and project phasing are as follows: many assumptions are made, the system will never have everything as wanted when needed, and system integration is minimal at first but improves over time. It is expected that the requirements will improve incrementally over time. Initial requirement will be established that will show what is needed and what is missing. Decisions were made so that Airspace Concept Evaluation System (ACES) Build 1 can be delivered at the end of calendar year 2002. As knowledge increases, decisions will be made on how to prioritize development. Developers will be asked to map their concept to the concept functional model (see Slide 8) using the spreadsheet shown in Slide 9.

VAMS Deliverables (Slides 11 - 19)

The capabilities and schedule for the ACES fast-time time deliverables (Build 1- Build 4) are shown in Slides 11-14. Similarly, the capabilities and schedule for the real-time deliverables (preliminary design review, critical design review, Capability 1, and Capability 2 are shown in Slides 15-18). These deliverables are dependent on information from the SEA and SLIC organizations as shown in Slide 19.

Challenges and Questions to Be Addressed (Slides 20 - 24)

The timing between when the requirements are specified and the needs of the VAST developers is off. Slide 20 shows some of the challenges the concept developers and the VAST software developers will face. To help meet this challenge, the questions that the VAST, SLIC, and SEA organizations will need to answer are given in Slides 21-23. Mr. Romer gave the answers he knew to date and received questions from the floor (see below). In addition, further details about the four task areas in VAST (ACES, real-time, human/team performance modeling, CNS modeling) were given. The status of the work in these four task areas will be given on day two of TIM 2.

Synopsis of Questions and Answers for Mr. Romer

During the presentation, Mr. Romer responded to the following questions from TIM participants as follows:

- What data analysis and data archiving capability will be available?

  These need further development and will be supplied when available.

- Are the delivery dates for Build 1 and Build 2 December 2002 and December 2003, respectively?

  Yes.

- Comment: The needs of the concept developers will cause the project timing problems and affect the completion of project milestones.

  Agree.

- Comment: Cooperation and sharing of information will be needed to answer the questions that you have posed.

  Yes. In addition, early blending and integration of concepts may be needed.

- Is it expected that the initial evaluation of concepts will be done by the concept developers followed by a more detailed evaluation using VAST?

  Yes. Dr. Roth will give the dates for when this is expected to be accomplished.

10.
System Analysis Tools

Mr. Sam Dollyhigh
Swales Aerospace

Mr. Gary Millsaps
Systems Analysis Branch
NASA Langley Research Center

A copy of the presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by the Presenters

The Systems Analysis Branch (SAB) at NASA Langley Research Center has a program similar to VAMS that is known as the System-Level Assessment of Operational Concepts, Technologies and New Vehicles in the National Airspace System. The SAB is developing a framework for the integrated systems analysis and engineering of air transportation system safety, capacity, economics, and environment. The program is evaluating advanced aviation concepts and technology impact on the aviation system. The impacts include technical performance and cost-effectiveness. The program provides guidance on integration with, and transition from, the current system to the future system. It provides for a slow and thorough transition. The program also provides technology investment portfolio guidance for the best objective function solutions.

Members of the SAB include Swales Aerospace, Aerospace Engineering and Research Associates, Draper Laboratory, TeamVision, and MIT/International Center for Air Transportation. This team supports Code R studies, Langley Research Center and Ames Research Center.

The SAB is developing a simulation and analytical tool suite similar to VAST. The difference between this tool suite and VAST is the integration and use of Commercial-Off-the-Shelf (COTS) Technology. The COTS tools to be integrated for this "closed loop" simulation will include the Future ATM Concepts Evaluation Tool (FACET), Post-Operations Evaluation Tool (POET), Reorganized ATC Mathematical Simulation (RAMS), and Aviation System Analysis Capability (ASAC). This tool collection will include airline cost models and aircraft efficiency modeling. A walkthrough of the data flow of the tool was provided (Slide 8).

Key differences between the VAMS project and the SAB tasks were highlighted. SAB is not a beta test for VAMS and will not go to the level of detail planned for VAMS. The SAB uses a bottoms-up approach to the total air transportation system analysis and impacts by evaluating local and regional impacts and rolling this up to a system-level analysis. The SAB is a NASA in-house analysis line organization with a broad cross-section of customers and time horizons.

The presenters concluded with a summary of the simulation and analytical components and the functional capabilities of the SAB.

Synopsis of Questions and Answers for the Presenters

After the presentation, the presenters responded to questions and comments from TIM participants as follows:

- Does the Systems Analysis Branch (SAB) support VAMS?

  Yes, this was included on a chart that was not presented.

- Are the SAB products available to VAMS and SLIC?

  Yes, there may be some licensing issues depending on the use.

- What is the fidelity of RAMS?

  There are over 300 metrics that can be provided by RAMS.

- Can the presenter share any lessons learned in the development of low-, medium-, and high fidelity models?

  Look at the questions you are trying to answer.

11.
Progress Toward Developing and Validating the Airspace Concept Evaluation System

Dr. Karlin Roth
Chief, Aerospace Operations Modeling Office
NASA Ames Research Center

A copy of Dr. Roth's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Dr. Roth

Session Purpose (Slides 1 – 2)

An in-depth progress report on the development and validation of the Airspace Concept Evaluation System (ACES) was given to the TIM 2 participants. Dr. Roth gave an overview of the ACES development plan and described how ACES will be used for concept evaluation. Dr. Roth was followed by other speakers who provided more detail on selected topics that included: modeling details, data flow, and validation of Build 1.

Development Plans and Status (Slides 3 – 11)

Based on reviews of the state-of-the-art in NAS modeling and simulation, the ACES developers selected and used the Department of Defense's (DoD) High Level Architecture (HLA) Run-Time Infrastructure (RTI) with agent-based software to develop a proof of concept prototype of a fast-time NAS-wide simulator. They expect to prove the feasibility of their approach with the Build-1 system and enhance the functionality of the modeling toolbox in later software builds. ACES requirements will be driven by the emerging VAMS concepts of operation. While the VAMS concept definitions are being refined, ACES development will proceed using a preliminary set of requirements. For Build-1, these modeling requirements are based on the current air transportation system. In addition to establishing the core ACES feasibility, current research focuses on adding cognitive human performance modeling, probabilistic forecasting, and on techniques for validating airspace models. The validation methodology adapts practices from military simulation and computational fluid dynamics. It will determine critical parameters needed to validate the models by assessing the fidelity of existing air transportation models. The developers will use existing NAS data sets to select "typical" and "standard" days in the NAS.

Preparing the Simulation System for Concept Evaluations (Slides 12 – 16)

Each ACES software build will be driven by the concepts that are being developed. In general, the ACES requirements must be available one year before the software is ready for use. This will allow the developers enough time to build a system to meet the new requirements and for the "in-house" team to check out the software to confirm its readiness for application. It is assumed that ACES will grow as a research capability and will not be used a production facility during the course of the VAMS project. NASA will only be able to supply minimal support for the system during the early releases. Extensive use of ACES will be used to check out the blended concept.

Synopsis of Questions and Answers for Dr. Roth

After the presentation, Dr. Roth responded to questions from TIM participants as follows:

- Can the current list of ACES requirements be made available to the concept developers?

  OK.

12.
Airspace Concepts Evaluation System (ACES): Overview

Mr. Douglas Sweet
Seagull Technology

A copy of Mr. Sweet's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Mr. Sweet presented an overview of the Airspace Concept and Evaluation (ACES) with a description of the prototype system and the upcoming Build 1 release.

Key Comments by Mr. Sweet

ACES Requirements (Slide 3)

The requirements are the "key challenges." First, the interdependencies between aircraft, controllers, airports, and weather must be represented. Second, the architecture must support very broad operational concepts—VAMS charter is to change the air traffic control operational paradigm. Third, implementation must be incremental, with components evolving from prototype to "production quality." Fourth and most important is to create a practical system where it is "easy" to develop and run simulations and easy to integrate new capabilities. Further, ACES must efficiently use its limited computational and network resources and provide the ability to tailor a simulation by combining different levels of fidelity.

Airspace Concept Evaluation (Slide 4)

The ACES framework is divided into pre-simulation, run-time, and post-simulation components. There are two critically important items. First is the toolbox representing a broad set of models of varying fidelity. The user selects a set of models from the Model Toolbox for a simulation to provide the appropriate fidelity and limit the overall simulation complexity. Second is the reconfigurable, scalable, and distributed run-time architecture that is distributed to provide adequate computational resources, scalable to accommodate simulations of varying complexity, and reconfigurable to allow a given set of models to be distributed across the available run-time computers.

ACES Core Modeling Approach (Slide 5)

All models are agent based where the agents communicate via messages to provide an object-oriented design. The agents map one-to-one onto the National Airspace System (NAS), allowing the agents to mimic real NAS components. This allows the components to be easily isolated and easily changed for the varying concepts and scenarios to be evaluated. Activities and messages are asynchronous and independent of each other.

Agent Example (Slides 6-11)

Sector agent is divided into multiple activities, each with multiple levels of fidelity, each capable of being separately and independently invoked. This one-to-one correspondence to the NAS allows for straightforward addition to or replacement of models. There are agent, activity, message, and data sets for this example. All models, whatever level of fidelity, use the same interfaces and data (Slide 10). The benefits include the ability to isolate functionality; modularity supports integration of new concepts and flexibility in allocating agents across the distributed framework.

High Level Architecture (HLA) and ACES Architecture (Slides 12 – 15)

High Level Architecture (HLA) provides a highly structured component organization. In HLA's Agent-Federate-Federation model, message traffic is always vertical, never horizontal; i.e., agents only communicate via their federate and federates only communicate through the HLA framework.

Legacy gateways provide a mechanism for incorporating existing models and simulations into ACES. Some will be easy, some hard, and some impossible. Resource constraints will limit the number of legacy models that can be included into ACES.

Airspace Concept Evaluation System (ACES) Development – Prototype Demonstration System (Slides 17 – 21)

It was for a "proof of concept" done in four months to use and integrate some existing tools and extend modeling capabilities. The scenario was NAS-wide en route simulation providing tests of fleet mix within and across sectors. It had a data gathering function that was used to produce candidate measures and metrics. There were three computer systems to prove distributed functionality.

Prototype Lessons Learned (Slide 22)

HLA supports distributed simulations, especially federation control and data collection.

The agent-based approach fits well with ACES requirements.

Build 1 must use more of HLA's capabilities, ease model integration, and provide a firm foundation for ACES.

ACES Build 1 System (Slides 23 – 27)

Build 1 establishes the foundation. The focus is on the current NAS because that is the only effective way to validate the models; i.e., existing models of today's components should produce results consistent with those seen in today's airspace. Validation is done with real-world data.

It provides initial capabilities and infrastructure for the modeling toolbox.

It has more agents with richer behaviors than the prototype. There will be a suite of computers that is "3X" larger over which to assign computational tasks to allow for some areas of high fidelity simulation.

Example Scenarios for Build 1 (Slide 28)

There will be five scenarios, all assessing NAS-wide effects of various changes, e.g., en route capacity increased by 25 percent, increased capacity for selected airports, reduced separation, planned airport expansions.

Summary (Slide 29)

ACES is distributed, scalable, and allows differing levels of fidelity.

Build 1 is an evolution of the prototype system.

Synopsis of Questions and Answers for Mr. Sweet

After the presentation, Mr. Sweet responded to questions from TIM participants as follows:

- What aircraft models are incorporated in Build 1?

  This will be discussed later.

- Are the simulation models deterministic or stochastic? Can you define the uncertainty of the models?

  Models are deterministic now; there will be a stochastic capability in later builds.

- Where have different levels of fidelity been implemented?

  For Build 1, varying fidelity models are only in the aircraft models and not for the other agents.

13.
Airspace Concepts Evaluation System (ACES): Build 1 Modeling

George Hunter
Seagull Technology

A copy of Mr. Hunter's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. Hunter

Model Functionality Overview (Slides 3 – 7)

The Airspace Concept Evaluation System (ACES) uses an agent-based paradigm. Within each agent there will exist a number of models to support that agent. The ACES Build 1 list of agents will include Flight, Air Traffic Control System Command Center (ATCSCC), Air Route Traffic Control Center (ARTCC), Traffic Flow Management (TFM), ARTCC Air Traffic Control (ATC), Terminal Radar Approach Control (TRACON) Traffic Flow Management (TFM), TRACON ATC, Airport TFM, Airport ATC, Weather, Airline Operations Center (AOC) Traffic Demand, and AOC Flight Control. A representative overview of these agents and the models within was presented on Slide 7.

Major Model Requirements (Slides 8 - 37)

The flight agent will model the en route aircraft trajectory including position, velocity, and fuel burn. The flight agent will incorporate the effects of winds in calculating the aircraft trajectory in the en route environment. The flight agent will model the terminal area aircraft trajectory including flight time and fuel burn. The flight agent will model nominal flight times for transitioning terminal airspace unless modified by the TRACON ATC agent to ensure separation of aircraft. The Multi-Purpose Aircraft Simulation (MPAS) will be used to model the trajectories.

The flight agent will use a nominal airport departure taxi time unless additional delays are assigned by the airport due to airport congestion (i.e., queuing delay). The flight agent will conform to nominal climb and decent profiles unless directed by Air Traffic Control. The flight agent will model at least 50 aircraft types. The flight agent will provide the data for data collection on each flight.

The ATCSCC agent will model the Monitor Alert function. This will include a sector-by-sector loading analysis provided by a look-up table of grid versus sector for each aircraft in the simulation. The ATCSCC agent will model the Ground Stop Program. The ATCSCC agent will model the Ground Delay Program on a first-come first-serve basis. The ATCSCC agent will provide the data for data collection.

The ARTCC TFM agent will analyze all predicted congestion events and determine if they can be handled with intra-Center restrictions or if they require a combination of intra-Center and inter-Center restrictions. The ARTCC TFM agent will analyze imposed adjacent ARTCC TFM restrictions and TRACON imposed TFM restrictions, responding with intra- and/or inter-Center restrictions. The ARTCC TFM agent will provide the data for data collection.

The ARTCC ATC agent will predict conflicts between aircraft in the en route airspace providing adequate time (TBD) to resolve the conflict. The ARTCC ATC agent will issue speed or vector advisories to aircraft to comply with conflict resolution and/or TFM constraints. The ARTCC ATC agent will deliver aircraft conflict free to adjacent facilities (ARTCC or TRACON). The ARTCC ATC agent will provide the data for data collection.

The TRACON TFM Agent will use a delay distribution function to determine the degree of TRACON delay absorption for delayed arrival aircraft. The TRACON TFM Agent will determine arrival and

departure flight times through its airspace. The TRACON TFM Agent will assign scheduled landing times consistent with airport arrival rates. Each TRACON will be represented as a generic TRACON with four independent arrival and four independent departure meter fixes. The TRACON TFM Agent will schedule TRACON flight times to be nominal flight times dependent on aircraft type.

The Airport TFM agent will send TFM restriction messages to the Airport ATC agent describing delay constraints on scheduled departure flights. The Airport TFM agent will determine the time-varying airport departure and arrival acceptance rates, accounting for meteorological conditions and capacity constraints. The Airport TFM agent will impose TFM restrictions for arrival flights within the TRACON and to adjacent ARTCCs in response to limited capacity at the airport. The Airport TFM agent will impose TFM restrictions for departure flights at the airport in response to limited capacity in the adjacent ARTCC.

The Airport ATC agent will revise the departure schedule to accommodate TFM restrictions. The Airport ATC agent will revise the departure schedule to reflect AOC flight delays and cancellations. The Airport ATC agent will determine takeoff and landing spacing requirements. The Airport ATC agent will assign actual times of runway departure and arrival time corresponding to the spacing requirements. The Airport ATC agent will assign actual gate departure times and actual gate arrival times. The Airport ATC agent will maintain data describing runway actual departure and arrival queuing. Each airport will be represented by independent arrival and departure traffic flows and arrival and departure capacities.

The Weather agent will use historical wind data sets (e.g., rapid update cycle data) to represent true winds. The Weather agent will interpolate between wind data sets to provide a 4D wind vector. The Weather agent will model inclement weather as capacity reductions of en route airspace or airports.

The AOC Flight Control agent will cancel flights in high-frequency markets when gate departure times exceed a preset time limit. The AOC Flight Control agent will impose airline-induced flight delays to preserve flight connections within preset time limits. The AOC Flight Control agent can exhibit different behavior through adjustment of cancellation and delay time limits. An example of the cancellation algorithm and the delay algorithm was presented.

The AOC traffic demand model will create a realistic set of scheduled flights using historical data files to represent the current NAS operational environment. The Traffic Demand Generation Process flow was presented. The traffic demand model will specify a gate-to-gate flight plan. The traffic demand model will use generic meter fixes for TRACON entry and exit points. The traffic demand model will provide the data for data analysis.

Synopsis of Questions and Answers for the Presenters

After the presentation, Mr. Hunter responded to questions and comments from TIM participants as follows:

- Does the list of requirements provide the concept developers with enough detail to get started?

  Yes. The Build 1 set of requirements are sufficient. However, the Build 2 set of requirements are needed now and then an iteration process for requirements will be needed. The requirements will need to be organized in such a way as to be useful for all concept developers to use.

- One concept developer desires 5,000 airports for their evaluation. Will that (5,000 airports) be a defined requirement the next time?

  Yes.

- When delay is measured in the AOC TFM model, is the effect of the propagation of delay measured through the model as well? Is the propagation of delay factored into the algorithms?

  Yes, depending on where in the system or model the delay occurs.

- When delay is measured in the AOC TFM model, is the effect of the propagation of delay measured through the model as well? Is the propagation of delay factored into the algorithms?

Yes, depending on where in the system or model the delay occurs.

- Will the detailed motion of the aircraft on the ground be modeled?

  No. Terminal models will include fuel burned and time but not position history.

- Does the airport queue model contain a model for multiple runways?

  No. VAST does not model complex airport configurations such as crossing runways or taxiways. The plan is to use a generic airport but use an aggregate capacity function that can be apportioned to delays.

- Are there any known incompatibilities in the agent models when they are used in a real-time environment?

  There are no incompatibilities known at this time. It is the intent to make the agents and simulation as plug and play as possible.

14.
Airspace Concepts Evaluation System (ACES): Data Flow

Mr. Douglas Sweet
Seagull Technology

A copy of Mr. Sweet's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Mr. Sweet focused on the inputs and outputs of ACES, Build 1.

Key Comments by Mr. Sweet

Inputs (Slides 3 – 6)

The user defines the input data. This includes the choice of airspace, demand, and initial meteorological conditions as well as the alterations in the scenario for airport and sector capacity changes. Capacity changes can be due to the usual items (e.g., weather) as well as for the introduction of new concepts.

While the default data sets reflect existing National Airspace System specifications, these are user alterable for the needs of each concept.

There are data sets needed for ACES configuration and initialization, e.g., agent to federate, federate to computer system, output of the flight demand model. For each concept, these are unlikely to change, once established.

Validation Outputs (Slides 7 – 10)

Flight data contains the flight identification (i.e., airline, flight number, airports, and unique internal number) as well as scheduled and computed times and fuel use.

A simplified set of ARTCC advisories by sector at 15-minute intervals is produced.

Traffic Flow Management advisories for airport, TRACON, ARTCC, and ATCSCC, are created and time tagged.

There are additional output possibilities (e.g., Conflict Detection & Resolution, flight delays, sector loading) being considered.

Synopsis of Questions and Answers for Mr. Sweet

After the presentation, Mr. Sweet responded to questions from TIM participants as follows:

- In the prototype, events along the flight path were shown. Will they also be available in Build 1?

  Not explicitly, but they will be derivable from the outputs.

15.
Airspace Concepts Evaluation System (ACES): Build 1 Assessment and Validation

Dr. Paul Abramson
PDA Associates

A copy Dr. Abramson's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Dr. Abramson presented an approach to validate the prototype system and the upcoming Build 1 release.

Key Comments by Dr. Abramson

Build 1 Assessment and Validation (Slide 1)

This presentation discussed how the assessment of Build 1 will be performed and how it will be validated that Build 1 produces realistic results.

Build 1 Assessment Objectives (Slide 2)

The objective of the assessment part of Build 1 will demonstrate assessments can be performed on the National Airspace System (NAS) under different operating conditions. This is a "walk before you run" objective.

Build 1 Validation Objectives (Slide 3)

That the simulation produces the correct order of magnitude compared to real-world data, and that it trends in the right direction, will be validated. For example, if traffic is increased, delays should go up for a given operating condition of the NAS.

ACES Build 1 Assessment and Validation (Slide 4)

To perform the validation:

- The metrics to be used will be defined and data will be collected from the simulation and the real-world
- The capability to perform certain assessments will be demonstrated.
- The simulation will be validated.

Assessment/Validation Scenarios (Slide 5)

The baseline set of the scenarios deal with the current NAS with no significant en route weather. So that a fairly normal NAS operation is studied, days that are not severely weather impacted will be used, and winds will be scripted with basically good weather at all airports. Data from low- and high-traffic days will be used.

If time permits, items such as the impact of a 20 percent increase in airport acceptance rates will be investigated. This will be done by inserting a variable in the airport arrival limit.

At bad weather at a few airports; for example, what if San Francisco (SFO) is fogged in for a few hours will hopefully be looked at.

Build 1 Metrics (Slide 6)

Basic metrics are flight event times, delays, total fuel consumed, controller workload, and traffic flow management restrictions.

Flight Events and Delays (Slide 7)

Flight event times are "candidates to validate against"; however, not all event times can be validated.

Flight Events Eye Chart (Slide 8)

Color code for the chart is as follows:

- Green: We think we can validate the item.
- Yellow: There are some problems with the accuracy of the data that will be used to validate the simulation against.
- Red: There is no data for validation.

Building the chart highlighted that there are some real-world problems associated with validation.

Total Fuel Consumed (Slide 10)

Fuel consumed will be computed, however real-world data on what fuel was consumed that day will not be collected and validation against fuel burn will not be performed. Nevertheless, it will be possible to compute a pretty good estimate of total fuel consumed.

Controller Workload Metrics (Slide 11)

We can't go back and retrofit instrumentation on a "prior day" so this data will not be available for the days picked. Therefore, we will not be able to validate these metrics.

TFM Restrictions (Slide 12)

TFM restrictions are basically counts of events and will be compared in a separate analysis to a real day.

Validation Process (Slide 14)

- Need to determine how ETMS data compares to averages obtained from Aviation System Performance Metrics (ASPM) data.
- Stage 1 validation: Comparing average simulation outputs with the averages obtained from the input data.
- Stage 2: Comparing simulated data to average ASPM data.
- The Project will run multiple days for every scenario and then look at averages across days to determine the "average behavior over multiple days."

Sources of Validating Data (Slide 16)

Main issue: "Is real-world data valid?"

Real-World Issues (Slide 17)

- A possible source of error: winds aloft are only measured and captured every 12 hours.
- The current National Airspace System data has delays of only 1 to 2 minutes.

Synopsis of Questions and Answers for Dr. Abramson

After the presentation, Dr. Abramson responded to questions from TIM participants as follows:

- Is there validation data for winds?

  Yes, NASA has winds validation data available.

- In reference to controller workload:

  The FAA has just completed a study on dynamic density. There is a large amount of data for four centers that has been validated. This data may be useful to the validation effort.

- All data sources, such as Aviation System Performance Metrics (ASPM), have built-in uncertainties. Do we know what these uncertainties are?

  ASPM has documented how accurate the data are. There are three kinds of problems: missing data, bogus data, and inaccurate data. We will be able to accommodate missing data, filter out bogus data, and make certain assumptions regarding the accuracy of the data (such as how accurate Enhanced Traffic Management System (ETMS) data are). We must be careful how we interpret ETMS data and account for problems in the data.

- How will ETMS data be used, particularly with respect to arrival times?

  ETMS data will be compared to the simulation outputs.

  If we deem that the data we have are inadequate, we will have to declare that we cannot validate that parameter.

- Can we track block times?

  An average over many runs will be used.

- The software development life cycle calls for unit- and module-level testing prior to system testing. Test runs can be performed on individual airports or individual sectors at unit test time, perhaps at higher fidelity. This can provide confidence on the individual models.

  There are two steps in proving the simulation. The first step is “verification,” when a sanity check of the individual models is made. The second step will test dynamic multi-aircraft validation.

  Unit testing will not catch all errors.

  Possible sources of errors in the models include whether the data we are using are valid, simplifications within the model, and errors within the model.

- Can we observe all events in the simulation?

  Yes, but some events are not simulated in a way that we want to validate.

  We cannot validate every event. Chart colors (Refer to Flight Events Eye Chart) are as follows: Red items are not observable, yellow items are observable with error, green are observable.

16.
Real-Time Validation Experiment

Ms. Sandra Lozito
Level 3 Lead, Systems Evaluation and Assessment (SEA)
NASA Ames Research Center

A copy of Ms. Lozito's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Ms. Lozito's presentation focused on the validation environment, not the validation concept.

Key Comments by Ms. Lozito

Task Schedule (Slides 2 – 3)

Initial validation will occur in 2004 time frame.

The System Evaluation and Assessment (SEA) sub-element is responsible for experimental requirements. This is underway with the recent delivery of requirements from the concept teams. The SEA sub-element will provide the pathway to future tests in the real-time environment.

Issues (Slide 4)

Validation testing must be relevant to the general VAMS themes implying that testing must encompass more than one airspace domain (e.g., TRACON + en route). Understanding and validating the connectivity issues will be important.

Parameters and Approach (Slides 5 – 13)

Validation will be sequential, leading up to the 2004 activity (and will not be big bang). Automation topics and their impact on human factors are a primary concern of the real-time validation.

While nominal operation allows comparison with data, abnormal operation and events will demonstrate how the real-time capability can be used to examine human factors issues.

Whereas the operations aspect is relatively settled, what airport to use for multiple arrival streams has not been decided upon.

Validation will include at least two simulation facilities. Candidates include the Crew Vehicle Systems Research Facility, Airspace Operations Lab, Future Flight Central, the Center/TRACON Automation System simulator at its North Texas Facility, and Vlab-like systems. For the latter, interconnection is a significant issue.

While the emphasis will be on validating the test environment, there are not enough details currently available to discuss that in depth.

Remaining Issues (Slide 14)

Though metrics for validation are not currently defined, "validatability" will be assumed. For example, time granularity metrics can be set neither too fine nor too coarse. There is a draft validation document in internal review that will become final in the next 3 to 4 months.

While the validation team is interested in how requirements between the real-time and fast-time environments relate, the mapping mechanism is unclear.

The integration of facilities and exchange of data between facilities are encouraging, but remain a risk item to accomplish within the time frame with the resource.

Synopsis of Questions and Answers for Ms. Lozito

After the presentation, Ms. Lozito responded to questions from TIM participants as follows:

- Is it possible to use an FAA facility (e.g., Tech Center Lab) for comparison?

  Yes, but the concern is both the time and cost of doing so. At least one past activity took a very long time and was more costly than anticipated.

  Harry Swenson added the following:

  - There are significant resource constraints on the validation activity.
  - Anything additional done in validation has to be both "quick and cheap."
  - "Quick" means that it fits into the schedule. "Cheap" means that it meets the budget constraints. If the FAA wants this done, then "show up with money."

17.
Virtual Airspace Modeling and Simulation Technologies (VAST): Real-Time Simulation Sub-Element

Mr. Scott Malsom
Level 4 Lead, VAST Real-Time Simulation
Ames Research Center

A copy of Mr. Malsom's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. Malsom

VAST Real-Time Overview (Slides 2 - 6)

The responsibility of Virtual Airspace Modeling and Simulation (VAST) is to develop the capability to simulate operations within the NAS to levels of fidelity sufficient for the research being performed within VAMS. This capability will provide a safe, cost-effective, common, flexible, and accessible platform for evaluating the concepts for future air transportation systems. Communications between the sub-elements and the concept developers is essential for the project to be successful.

VAST Real-Time (VAST-RT) will receive concepts to be simulated from two sources. The System Evaluation and Assessment sub-element can provide concepts directly to VAST-RT when such concepts require real-time simulations as a part of their development cycle. VAST-RT will also receive input from Airspace Concept Evaluation System (ACES) when ACES has need of detailed studies to support work it is performing. When this occurs, ACES will provide system-wide studies of the overall concept. Then ACES, acting through SEA, will provide requirements for detailed VAST-RT studies. VAST-RT will examine the detailed issue using real-time simulation techniques and provide refined data to ACES for their next non-real-time study. ACES will make additional studies and this process will repeat as often as required. The starting point will be the existing simulations. The next step will be to add revolutionary ideas to the simulations and then improve the simulations to meet VAMS objectives.

VAST-RT Concept (Slides 7 – 9)

The VAST-RT concept has four major areas. The first area is the Architecture that will provide overall system communications, data collection, synchronization, and simulation control functions. The second area is the models that will be attached to the architecture and provide the functionality for performing the simulation or evaluating the concept. Examples of models may be the aircraft target generator for providing aircraft to populate the simulated National Airspace System; weather models; and models of specific Air Traffic Management/Air Traffic Control functions such as voice communications between controller and aircraft. An example of this was given where the airport, tower, and departure control model was replaced by a representative concept on Slide 9. Some models will vary in fidelity depending on the concept. The third area is the Collaborative Development Environment (CDE) that will be the user interface to the system. The fourth area is comprised of all of the work required to integrate the above into a functional system. Examples of this work include alignment of visual databases and negotiation of disparate coordinate systems.

System Components (Slides 10 - 30)

The core of the architecture will be a High Level Architecture (HLA)-based backbone of networks. The VAST-RT is best visualized as a series of data buses to interconnect all the participants and the models. These data buses will include the simulation data bus, the audio communications data bus, the streaming video bus, and an administrative bus.

Other components will include the VAST HLA Run-Time Infrastructure Executive, the Collaborative Development Environment (CDE), Air Traffic Control Simulators (controllers and/or pilots), VAST-RT simulations (target generation, weather, and communication, navigation and surveillance), and the VAST databases and data collectors. Connecting this architecture to other possible components will be HLA bridges. HLA bridges will allow connections to legacy systems to allow expansion of the VAST-RT without developing new or common simulations.

The CDE will be the user interface to the VAST-RT. It is envisioned that the CDE will be as intuitive as possible. It will be a graphic user interface (GUI)-based design. Component pieces of the CDE will be a network GUI, a Data Review GUI, communications including voice, data, and e-mail, and connectivity to other user tools.

Synopsis of Questions and Answers for Mr. Malsom

After the presentation, Mr. Malsom responded to questions and comments from TIM participants as follows:

- Who provides the security for the Collaborative Development Environment? Is there an overlying security blanket?

  Yes, security and firewalls will be included in the overall architecture.

- Who manages the actual configuration of the CDE and toolset?

  This cannot be answered at this time. It is planned to have that answer in 6 to 8 months.

- How does SEA plan to prioritize between researcher needs if they cannot use the system simultaneously.

  SEA is going to take their best shot at what can be done. A series of meetings will be needed with the right people and the concept developers to discuss this issue. Some negotiation will be required.

- Will researchers be able to see early versions of the toolbox?

  Yes. It is the intent of the program to provide incremental releases of the toolbox between now and April 2004. The releases will be quarterly and include increased functionality in each release.

- Will there be a working group or industry panel of key people involved early in the start-up activities of the architecture definition?

  Yes. Key people are expected to contribute and some have already identified.

- The charts show a VAST database. Is that a data repository?

  The team is looking at ways to collect huge amounts of data and correlate it in such a way as to be useful to the researchers. The team is considering a relational database but the final solution could be over a year away.

18.
Virtual Airspace Modeling and Simulation Technologies (VAST): Human and Team Modeling

Dr. Roger Remington
Level 4 Lead, VAST Human and Team Modeling
NASA Ames Research Center

A copy Mr. Remington's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Mr. Remington presented his approach to human performance modeling.

Key Comments by Dr. Remington

Human and Team Modeling (Page 1)

Slides are from a tutorial on our modeling system.

Goals (Slide 3)

One of the themes of this presentation is that it is very difficult to build a good computational model of human behavior to the degree that you can use items built in one case for another.

These are the same three goals that have existed even prior to this project.

Focus has shifted from the "development of a computational architecture that supports rapid configurability and promoting the reuse of software modules across scenarios" to a focus on providing "models of human performance that can be used in fast-time simulation evaluations of airspace concepts."

What Modeling and Simulation Need to Address (Slide 4)

The slide was provided by Dr. Len Tobias.

Items on this slide translate into requirements for human and team modeling.

Every concept includes controllers, air traffic control, aircrews, pilots, and airline operations centers, and will, therefore, have to model these three classes of agents.

Operationally useful predictions must be made, such as system throughput (capacity) and error modeling, and how sensitive the system is to deviation from nominal human performance. In other words, in which scenarios are human performance the critical component and how can they be quantified.

Another set of requirements is to have our human performance models operate in the simulation environment Dr. Roth is putting together for the toolbox (e.g., we have to operate with HLA-compatible simulations).

Team performance needs to be modeled. Less is known about modeling team performance than is known about modeling individual performance.

Action item: Dr. Remington asked the audience to provide ideas on how best to model team performance.

Requirements for Human and Team Modeling (Slide 5)

This slide has also been provided by Dr. Len Tobias.

Some or all of these need to be examined to see what the human performance requirements are and where the humans fit in. This requires rapid turnaround of models from one domain to the next.

Complex Dynamic Environments (Slide 8)

People are juggling lots of things at once. There is some predictability, but there is also an amount of uncertainty. There are some behaviors that are relatively routine, but there are interruptions that occur, changes in equipage occur, and failures happen. You have to be able to deal with these. This is called a mixed initiative situation, meaning that there are other players in the game who are making decisions independent of you. The other players can be other people or pieces of automation. These kinds of behaviors need to be able to be modeled.

Usability Analysis (Slides 11 – 13)

This slide provides an example of this kind of analysis. This is a mockup that has been used in the Airspace Operations Lab at Ames for a while. Our focus is what are its characteristics during routine use. It is assumed that the operator is skilled and knows what to do and how to do it. Then it can be asked: "how easy is the system to use," "how much time does it take to perform standard tasks," and "what is the effect on concurrent tasks."

APEX and Critical Path Method variant of Goals, simple Operators, Methods (CPM-GOMS) tool to analyze human performance (Slide 14)

The system we will use is called APEX. APEX is a computational architecture for modeling human performance. It is a software system implemented in the LISP language. It is a language for representing tasks, human resources, and a scheduler that schedules the resources. It has no built-in theory of human resource interaction.

APEX Approach (Slide 15)

APEX is not a production system. All knowledge is represented as procedures. It is a procedure-driven system with a scripting language for procedures. It is a flexible environment in which the modeler can represent a theory that specifies the appropriate constraints (for example, you can model at the level of "hands" or at the level of "equipment" or an individual person vs. the entire TRACON).

GOMS Components (Slide 19)

GOMS is composed of two components: a task analysis component and a performance computation component.

The task analysis component organizes tasks in a hierarchy containing goals and sub-goals. However, only leaf node activities are measured.

The performance computation component computes performance. Leaf nodes are assumed to take time (they can be serial and parallel).

Variety of GOMS (Slide 20)

Keystroke-Level Model has a very flat structure, can be built relatively quickly, and provides a crude first order approximation of behavior. It does a pretty good job of predicting the behavior of reasonably well-trained people.

Card-Moran-Newell GOMS is the "standard" version of GOMS.

Cognitive-Perceptual-Motor GOMS provides good predictions.

ATM Study (Slides 24 – 39)

The air traffic management study was funded under several base research projects, illustrating leverage of base research into applied domains.

Significance (Slide 40)

Large-scale dynamic environments can be modeled. Our ability to model large-scale dynamic environments is limited to 30 to 60 seconds maximum time for each model.

Some of Dr. Kevin Corker's work may be used to support this effort.

So far about 20 templates have been built. How many more are needed will be determined afteer air traffic control is studied.

FY 02 Milestones (Slide 42)

Papers shown on the slide are available at ftp://eos.arc.nasa.gov.

Out-Year Milestones (Slide 43)

The task is working with Dr. Kevin Corker toward modeling human multitasking characteristics relevant to aircrew, controller, and dispatcher operations.

Action Item: Attendees were asked to provide thoughts on the issue of investigating "human factors issues associated with supervisory control and interaction in teams."

Synopsis of Questions and Answers for Dr. Abramson

After the presentation, Dr. Remington responded to questions from TIM participants as follows:

- How are delays caused by human operators going to be modeled?

  We currently have recordings of controller/aircraft interactions. We have already created plots of average times and distributions of times of these interactions. A simulation of a TRACON can include such things as a controller's being interrupted and computing how sensitive the system is to the event and what effect it has on traffic flow.

- How far are we from NAS-wide and regional simulations capable of assessments of the impact of different concepts and tools?

  First the agent procedures must be defined.

  You need to decide what you want workload to be.

- How can workload be modeled?

  The number of decisions per unit time, free time, etc., can be measured. Workload can then be extracted from this data. It also must be agreed on by what we mean by workload. We should not try to measure "subjective" workload.

- Why aren't existing models being used (such as MIDAS)?

  CPM-GOMS was selected because it has a long history of use and is theoretically well grounded.

19.
Virtual Airspace Modeling and Simulation Technologies (VAST): Communication, Navigation, and Surveillance (CNS) Modeling

Mr. Steven Mainger
Level 4 Lead, VAST CNS Modeling
NASA Glenn Research Center

A copy of Mr. Mainger's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. Mainger

Objectives (Slide 2)

Develop communication, navigation and surveillance (CNS) modeling requirements that support airspace concept evaluation based on current rules.

Develop CNS models for today's system and traffic.

Status (Slide 3)

The list of CNS modeling and simulation needs is a "real short list" based on existing systems. Other activities can be leveraged for candidates.

The critical design review for the CNS models and traffic profiles was August 23, 2002.

Emerging CNS Infrastructure (Slide 5)

European Union is dividing the 25 KHz into three 8.33-KHz bands, but that idea has not caught on in the United States.

Bit-oriented data — VHF Data Link (VDL) Modes 2, 3, 4—are emerging technologies.

Aeronautical Telecommunications Network (ATN) communication networks are in the concept stage in Europe, but have no current U.S. presence.

The Global Positioning System with Wide Area Augmentation System (WAAS) / Local Area Augmentation System (LAAS) is fast becoming the navigation aid.

There are multiple candidates for surveillance radar. Which will emerge is unknown.

Which CNS Components Need to Be Modeled? (Slide 6)

There are candidates for communication (voice and digital), navigation, and surveillance. The choice will be priority based within the resource limits. The one issue is whether the near-term choice would be different from the far-term choice.

Synopsis of Questions and Answers for Mr. Mainger

There were no questions for Dr. Tobias from TIM participants.

20.
Next Steps and Preview of Technical Interchange Meeting #3

Mr. Tom Romer
Level 3 Lead, Virtual Airspace Modeling Technologies (VAST)
NASA Ames Research Center

A copy of Mr. Romer's presentation is attached as part of the appendix and is available on the Web at http://www.asc.nasa.gov/vams/.

Key Comments by Mr. Romer

The Single Slide

The tentative dates for Technical Interchange Meeting Number 3 are January 14-16, 2003.

The focus will be on scenarios as a means of sharing concepts.

Each of the concepts will share the self-evaluation scenario and its metrics.

The SEA team will present the common scenario(s) and the common metric set.

Concept-blending discussions will continue.

There will be a discussion of ACES Build 1, which is planned for December 2002 delivery.

John Cavolowsky will discuss Economic Assessment of Transportation Needs (EATN).

Synopsis of Questions and Answers for Mr. Romer

There were no questions for Mr. Romer from the TIM participants.

Appendix A
NASA VAMS Project TIM 2 Acronyms

Acronym	Definition
AAC	Advanced Airspace Concept
AACS	Automated Airspace Computer System
AC	Aircraft
ACES	Airspace Concept Evaluation System
ADS-B	Automatic Dependent Surveillance-Broadcast
AOC	Airline Operations Center
AOL	Airspace Operations Lab
ARTCC	Air Route Traffic Control Center
ASAC	Aviation System Analysis Capability
ASPM	Aviation System Performance Metrics
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
CDE	Collaborative Development Environment
CD&R	Conflict Detection & Resolution
CDR	Critical Design Review
CDTI	Cockpit Display of Traffic Information
CNS	Communications, Navigation and Surveillance
CPDLC	Controller-Pilot Data Link Communications
CPM-GOMS	Critical Path Method variant of the Goals, simple Operators, Methods tool to analyze human performance
CTAS	Center/TRACON Automation System
CTOC	Centralized Terminal Operation Control
CVSRF	Crew Vehicle Systems Research Facility
DOD	Department of Defense
EATN	Economic Assessment of Transportation Needs
ETMS	Enhanced Traffic Management System
FACET	Future ATM Concepts Evaluation Tool
FF	Free Flight
FFC	Future Flight Central
FMS	Flight Management System
GA	General Aviation
GFI	Government Furnished Information

Acronym	Definition
GO-SAFE	Ground-Operation Situation Awareness and Flow Efficiency
GPS	Global Positioning System
GUI	Graphic user interface
HITL	Human in the Loop
HLA	High-Level Architecture
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
LAAS	Local Area Augmentation System
LISP	A programming language widely used in artificial intelligence research designed to process data consisting of lists.
MIDAS	Man Machine Integration Design and Analysis System
MPAS	Multi-purpose Aircraft Simulation
NAS	National Airspace System
NEXCOM	NEXt generation air/ground COMmunication program
NRA	NASA Research Announcement
NRT	Non-Real-Time
NTX	North Texas Facility for CTAS Research
PDR	Preliminary Design Review
POET	Post-Operations Evaluation Tool
PTP	Point-to-Point
RAMS	Reorganized ATC Mathematical Simulation
RT	Real-time
RTI	Run-Time Infrastructure
RUC	RUC is a high-frequency data assimilation and mesoscale numerical weather prediction system.
SAB	Systems Analysis Branch
SATS	Small Aircraft Transportation System
SEA	Systems Evaluation and Assessment
SLIC	System-Level Integrated Concepts
TBD	To Be Determined
TFM	Traffic Flow Management
TIM	Technical Interchange Meeting
TIS-B	Traffic Information Services-Broadcast
TRACON	Terminal Radar Approach Control
TSAFE	Tactical Separation Assurance Flight Environment
VAMS	Virtual Airspace Modeling and Simulation
VAST	Virtual Airspace Simulation Technologies

Acronym	Definition
VDL	VHF Data Link
WAAS	Wide Area Augmentation System
WX	Weather

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Appendix B

Attendee List

Paul Abramson	PDA Associates
Kenneth Arkind	Raytheon Company
Rose Ashford	NASA Ames Research Center
Larry Babb	Computer Science Corporation
Robert Beard	Computer Sciences Corporation
Karl Bilimoria	NASA Ames Research Center
Lisa Bjarke	NASA Ames Research Center
Karen Buondonno	Federal Aviation Administration
Brian Capozzi	Metron Aviation, Inc.
Ted Carniol	Metron Aviation
John Cavolowsky	NASA Ames Research Center
Chun-Hung Chen	George Mason University
Victor Cheng	Optimal Synthesis
William Cleveland	NASA Ames Research Center
Thomas Cochrane	Raytheon ITSS
Brad Cohen	The Boeing Company
Kevin Corker	San Jose State University
George Couluris	Seagull Technology, Inc.
Steven Cowart	NASA Ames Research Center
Goli Davidson	Metron Aviation, Inc.
Dallas Denery	NASA Ames Research Center
Sam Dollyhigh	NASA Langley Research Center
Thomas Edwards	NASA Ames Research Center
Heinz Erzberger	NASA Ames Research Center
John Fergus	Northrop Grumman IT
Robert Fong	NASA Ames Research Center
David Foyle	NASA Ames Research Center
Melinda Gratteau	Raytheon ITSS
Steven Green	NASA Ames Research Center
Shahab Hasan	Logistics Management Institute (LMI)
Susan Heers	Monterey Technologies, Inc.
Susan Hinton	Raytheon ITSS
Urmila Hiremath	The Mitre Corporation
Becky Hooey	Monterey Technologies, Inc.
Alex Huang	Seagull Technology
George Hunter	Seagull Technology, Inc.
Carla Ingram	Northrop Grumman Information Technology
Douglas Isaacson	NASA Ames Research Center
Robert Jacobsen	NASA Ames Research Center
Kevin James	NASA Ames Research Center
David Jara	San Jose State University
Matthew Jardin	NASA Ames Research Center
Randall Kelley	Seagull Technology
Robert Kerczewski	NASA Glenn Research Center
Rod Ketchum	FAA ACB-100
Brian Kiger	Seagull Technology, Inc.
Richard Kirsten	Computer Sciences Corporation

Parimal Kopardekar	Federal Aviation Administration
Jimmy Krozel	Metron Aviation
Andrew Lacher	The Mitre Corporation
Ronald Lehmer	Northrop Grumman Information Technology
Diana Liang	Federal Aviation Administration
Sandra Lozito	NASA Ames Research Center
Steven Mainger	NASA Glen Research Center
Scott Malsom	NASA Ames Research Center
Lynne Martin	San Jose State University
P.K. Menon	Optimal Synthesis
David Meyers	USRA/RIACS
Larry Meyn	NASA Ames Research Center
Mary Miller	Raytheon Company
Gary Millsaps	NASA Langley Research Center
Raymond Miraflor	NASA Ames Research Center
Richard Page	Federal Aviation Administration
Russell Paielli	NASA Ames Research Center
Kee Palopo	Raytheon ITSS
Jay Pollack	Computer Science Corporation
William Preston	Raytheon ITSS
Leighton Quon	Northrop Grumman/Logicon
John Rekstad	Federal Aviation Administration
Roger Remington	NASA Ames Research Center
John Richards, Jr.	Titan Systems
Paul Rigterink	Computer Sciences Corporation
Tom Romer	NASA Ames Research Center
David Rosen	Orbital Sciences
Vernon Rossow	NASA Ames Research Center
Karlin Roth	NASA Ames Research Center
David Schleicher	Seagull Technology
Ewald Schoemig	The Boeing Company
Al Schwartz	Federal Aviation Administration
Barry Scott	Federal Aviation Administration
Tom Sharkey	Monterey Technologies, Inc.
David Signor	Seagull Technology
Alvin Sipe	The Boeing Company
George Skaliotis	USDOT / Volpe Center
George Solomos	The MITRE Corporation
Banavar Sridhar	NASA Ames Research Center
Edward Stevens	Raytheon Company
Barry Sullivan	NASA Ames Research Center
Douglas Sweet	Seagull Technology, Inc.
Harry Swenson	NASA Ames Research Center
Leonard Tobias	NASA Ames Research Center
Earl VanLandingham	NASA Ames Research Center
Paul van Tulder	The Boeing Company
Savita Verma	San Jose State University
Chris Wargo	Computer Networks & Software, Inc.
DelWeathers	NASA Ames Research Center
Sheryl Wold	Raytheon ITSS
Robert Zimmerman	Raytheon ITSS

Appendix C
Presentations

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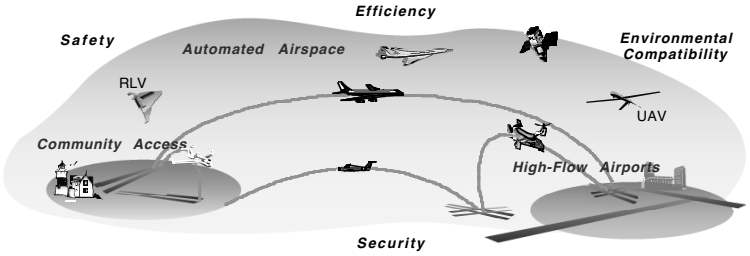
VIRTUAL AIRSPACE MODELING AND SIMULATION

Technical Interchange Meeting II

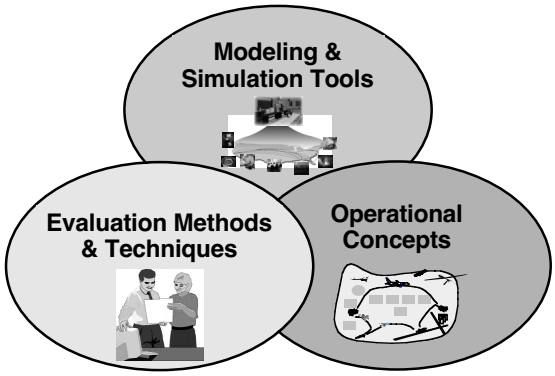


Harry Swenson
Project Manager
NASA Ames Research Center

August 27-28, 2002

Project Vision

The Virtual Airspace Modeling and Simulation Project will provide the technologies and processes for conducting trade-off analyses amongst future air transportation system's concepts and technologies



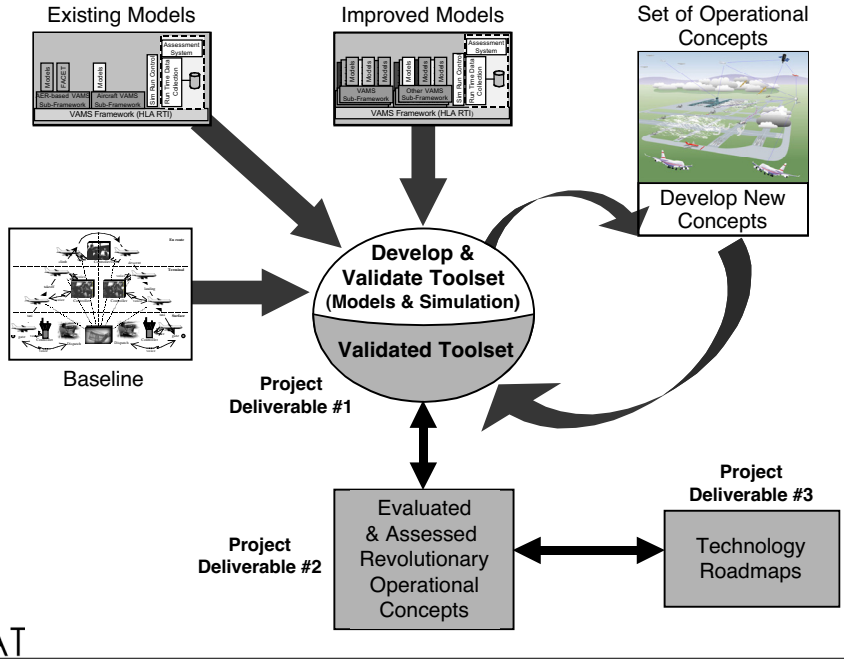
VAMS Technical Objectives

Virtual Airspace Modeling & Simulation - TIM #2

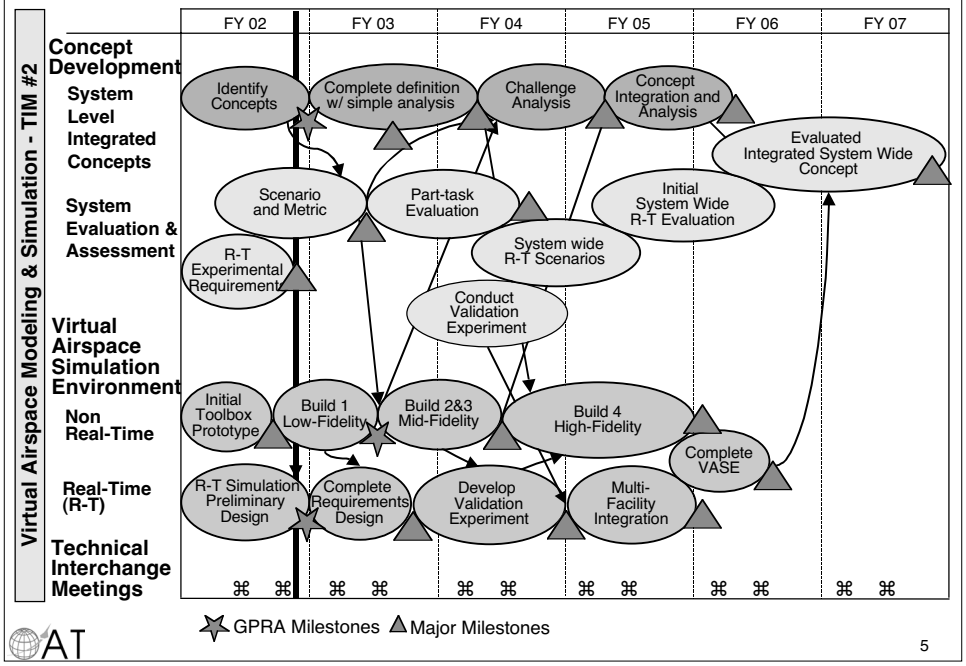
- **Develop and validate modeling and simulation tools providing the multi-objective (safety, capacity, cost) trade space to analyze air traffic management (ATM) concepts.**
- **Create operational concepts and conceptual architectures that can be used to define the next generation air transportation system, and develop technology roadmaps, to meet long-term Enterprise goals.**
- **Develop operational scenarios, metrics and evaluation methodologies to assess potential operational concepts and technologies to meet the forecasts across the trade space.**

Technical Approach

Virtual Airspace Modeling & Simulation - TIM #2



VAMS Roadmap



VAMS

Virtual Airspace Modeling & Simulation - TIM #2

- Status
  - **Concept developers have identified their Operational Concepts and prepared preliminary definitions and scenarios**
  - **Prototype ACES developed and demonstrated**
  - **VAST Initial Real-time Simulation defined**
  - **VAST Real-Time Simulation Preliminary Design Review Conducted**
  - **ACES Build 1 "VAST Non-Real-Time state-of-the-art airspace models toolbox with the ability to assess economic impact of new technology and NAS operational performance and the ability to model the dynamic effects of interactive agents" is on schedule for its delivery this fall**
  - **Common Scenario set development is focused and on schedule**
  - **FY03 Funding cut due to HQ infrastructure of $1.8 Million will cause some refocusing of the Real-Time Simulation development effort**

Virtual Airspace Modeling and Simulation Project (VAMS)
Technical Interchange Meeting #2

Tom Romer
VAST Lead
NASA Ames Research Center

VAMS TIM #2
Moffett Training and Conference Center
August 27-28, 2002

Outline

- TIM #2 Objectives
- Agenda
- Logistics
- TIM #2 Content

TIM Objectives

- Continue information exchange with VAMS participants
- Describe VAST requirements definition process
- Define and begin to address current VAST challenges
- Report VAST definition and development status
- Continue development of scenario and metric definitions

TIM Agenda

PST	27-Aug Tuesday	28-Aug Wednesday
7:30	Facility opens and Meeting Registration	Facility opens
7:45		
8:00		Daily Agenda
8:15		
8:30	NASA Greeting (Swenson)	VAST Non-Real-Time (Roth)
8:45	TIM #2 Overview (Romer)	Overview (Sweet)
9:00	ATS Traffic Demand Modeling (Cavolowsky)	Models (Hunter)
9:15		Data (Sweet)
9:30	Scenarios and Metrics (Lozito)	Validation (Abramson)
9:45		
10:00	Break	Break
10:15		
10:30	Breakout **Scenarios and Metrics** (3 separate parallel sessions)	VAST Non-Real-Time (cont.)
10:45		
11:00		
11:15		Real-Time Validation Experiment (Lozito)
11:30		
11:45		Catered Lunch in Patio Room
Noon	Catered Lunch in Patio Room	
12:15		
12:30		
12:45		
1:00		VAST Real-Time (Malsom)
1:15	Concept Modeling Requirements (Tobias)	
1:30		
1:45	Concept Portrayal Response (James)	
2:00		
2:15		
2:30	Report on Breakout	
2:45		Break
3:00	Break	
3:15		Human/Team Modeling (Remington)
3:30		
3:45	VAST Requirements (Romer)	
4:00		CNS Modeling (Mainger)
4:15		
4:30	System Analyis Tools (Yackovetsky)	
4:45		Next Step and Preview of TIM #3
5:00	Wrap-up	

TIM Logistics

- Phone Calls
  Messages can be left at (650) 604-2926 or 604-2082
- Computing
  Macintosh computers and hookups for laptops are available for your use in the Fireside area.
- Refreshments & Registration
- Breakout Assignments
  - Patio
  - North wing
  - Ballroom
- Restrooms
  Located on the right side of the ballroom and on your left just as you past the registration area.

TIM #2 Content

- **VAST Requirements Definition Process**
  - Demand forecasting and modeling
  - Scenarios and metrics development
  - VAMS-concepts modeling and simulation requirements
- **Synergy with other modeling and simulation efforts**
- **Definition and development status**

Airspace Systems Program

Socio-Economic and Demand Forecasting

John A. Cavolowsky
Assistant Director
Airspace Systems Program

August 27, 2002

Objective

- The NASA Aeronautics research program has increased its emphasis on ATM technologies in response to heightened national needs. (VAMS)
- NASA is considering programs to develop technologies for an advanced NAS.
- However, it is necessary to have a solid understanding of the broader economic environment in which those technologies will operate.
- A more complete understanding of the potential environments in which NASA research will operate enables solutions that are robust under a wide variety of conditions.

Problem Definition

- In order to develop a research program that will provide demonstrable benefits to taxpayers, travelers, and industry, the Airspace Systems (AS) program needs to understand how national economic conditions, demographic trends, and other factors affect the Nation's need for transportation, and air transportation in particular.
- This includes the traditional factors (such as price, population, GDP, and demographics - as well as new security concerns) and how they will affect the need for NASA sponsored research.

Study Approach

- The focus of this study will be to develop an understanding of the role of transportation in general and air transportation in particular within the U.S. economy, the major determinants of the demand for air transportation, and how an intermodal perspective may affect our understanding of air travel demand.
- The principal mechanism for developing this understanding will be the definition of a set of operational-level scenarios that depict the potential future environment for the global air transportation system. These scenarios will include economic conditions, security considerations, airport and airspace capacity, and the global political environment.
- More detailed descriptions of the impacts of these operational-level scenarios will be developed, in terms of their effects on air travel demand volume and its distribution.

Supporting Organizations

- LMI
- GRA
- Volpe National Transportation Systems Center
- Affiliated consultants and universities

Currently engaged in a 6-month effort

Develop Transportation Scenarios

The Future is Uncertain.
Technology lead times can be long.
Conditions are likely to change.

- Identify driving forces
- Determine their potential variation
- Create scenarios spanning the variables
- Examine the resulting scenarios and select a subset for detailed study
- Study system trends for the selected scenarios, evaluate costs, and assess risk factors

Limited resources must be allocated to areas that are most likely to achieve success in scenarios with the greatest probability of being realized.

Limits and Uncertainties

- Focus on a limited number (4 to 6) of highly plausible operational scenarios rather than attempt to address every possible scenario.
  - When selecting the scenarios for detailed study, care will be given to generate a variety of orthogonal scenario variables.
- Forecasting the future becomes increasingly hard as the time horizon is extended.
  - Consequently, we will focus on a 20 year forecast (i.e. 2022)

Three Part Effort

- Describe the current state of knowledge on the relationship between transportation and the economy and how that affects the NASA airspace systems research program.
- Review the previous scenarios to include those developed for NASA by the National Research Council ("Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise"), and revise, update, and expand them as required to reflect current and future conditions.
- Develop a set of demand forecasts, incorporating both aggregate travel volumes and its distribution among airport-pairs and air vehicles, for each of the defined scenarios. Develop a schedule of commercial and GA flights for each of the scenarios.

Activity One

- Conduct literature search of past studies:
  - Generate insights into the interdependence of the broad economic environment, the role of transportation, and NASA's airspace systems research
- Examine usage of air transportation by sectors of the economy:
  - Identify sectors that are largest users of passenger and cargo air transportation
  - Identify sectors that are particularly dependent on air transportation in terms of input costs

Air Transport and the Economy

- Catalog and assess existing models:
  - ASAC Air Carrier Investments Model (ACIM)
  - ASAC Air Carrier Cost-Benefit Model (CBM)
  - National Aeronautics Cost-Benefit Analysis Model (NACBA)
  - Population and employment demographic models
  - Mode choice models
  - Economic impact models
  - others
- Identify strengths and weaknesses of economic models and their measures:
  - Measures that appeal to technical audiences (e.g. CBO, GAO, OMB, etc.)
  - Measures for lay audiences

Activity Two

- Review external aviation forecasts
- Develop market segments of interest
- Identify demand drivers
- Identify supply issues
- Align demand with scenarios
- Input to Activity 3

Review External Aviation Market Forecasts

What are the smart people saying?

- Boeing
- Airbus
- FAA
- IATA
- ICAO-FESG (Finance and Economic Sub-Group)
- Others

Forecasts ranging in scope from 10 to 50 years

Aircraft Market Segments

- Regional
  - GA
  - Rotary
  - Turbo Prop
  - RJ
- Mainline
  - 100, 150, 200, 300, 400+ seat
  - Conventional subsonic
  - High speed subsonic
- All cargo
- other

Demand Drivers

- Economic growth
- Full price of travel:
  - Access and travel times
  - Access and travel costs
  - Access and travel schedule availability
  - Relative attractiveness of competing modes

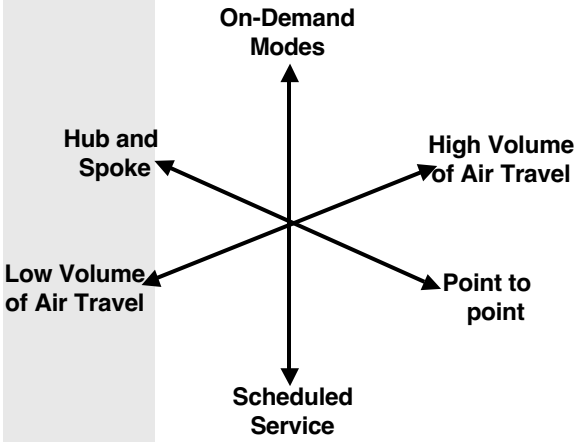
Supply Issues

- Congestion/delay
- Security/risk perceptions
- Security time and money costs
- Fuel costs
- Air navigation service/airport charges (high fixed cost)

Align Demand to Scenarios

- Travel market segments:
  - Domestic/international
  - Business/vacation/visit friends and relatives
  - Cargo/passenger
  - Scheduled/on-demand
  - others
- Scenario issues
  - Passenger growth
  - Cargo growth
  - Environmental limits
  - Fuel price shocks
  - World tensions
  - others

Activity 3: Axes of Interest



Parameter Definitions

- Volume of Air Travel is a function of overall health of economy, demographic trends, security issues, and relative attractiveness of competing surface modes.
- Scheduled versus On-Demand attribute measures the degree to which scheduled air carriers satisfy air travel demand versus GA, SATS, etc.
- Hub and Spoke versus Point to Point attribute measures the degree to which passengers travel directly from their true origin to their true destination.

Traffic Schedule Inputs

- Commercial traffic:
  - Time-of-day patterns for both airports and O&D markets and the simulated airline operation strategies for schedule generation
- GA:
  - Based on SATS modeling work
  - Terminal operation forecast, distance profile, and the gravity model for the O&D demand
- Cargo
  - TBD

Outputs from Activity Three

- A set of airport demand forecasts for each of the scenarios defined under activity two:
  - Commercial flights by airport-pair
  - GA flights by airport-pair
  - Cargo flights by airport-pair

Follow-on Activities

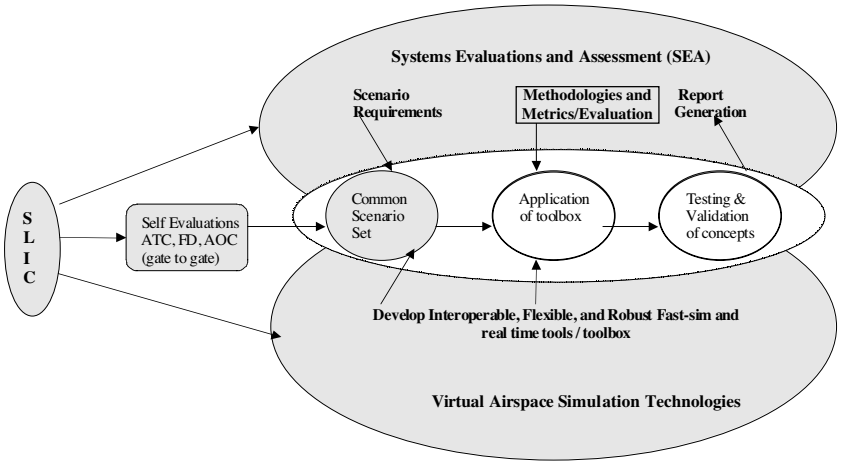
- Identify institutional factors and societal concerns affecting changes in the aviation system
- Identify inhibitors to system improvements

Systems Evaluation and Assessment (SEA) Sub-Element

Common Scenarios and Metrics Requirements

Sandy Lozito
Level 3 Manager
SEA Sub-element

System Evaluation and Assessment Relationship between the Sub elements



System Evaluation and Assessment General Tasks

- Develop scenarios and metrics for evaluation of the SLIC concepts
- Conduct an initial validation assessment of the VAST real-time tools
- Conduct an initial assessment of the selected concepts
- Conduct an initial assessment of the integrated concepts
- Conduct the final evaluation of the integrated concept(s) using the VAST tools

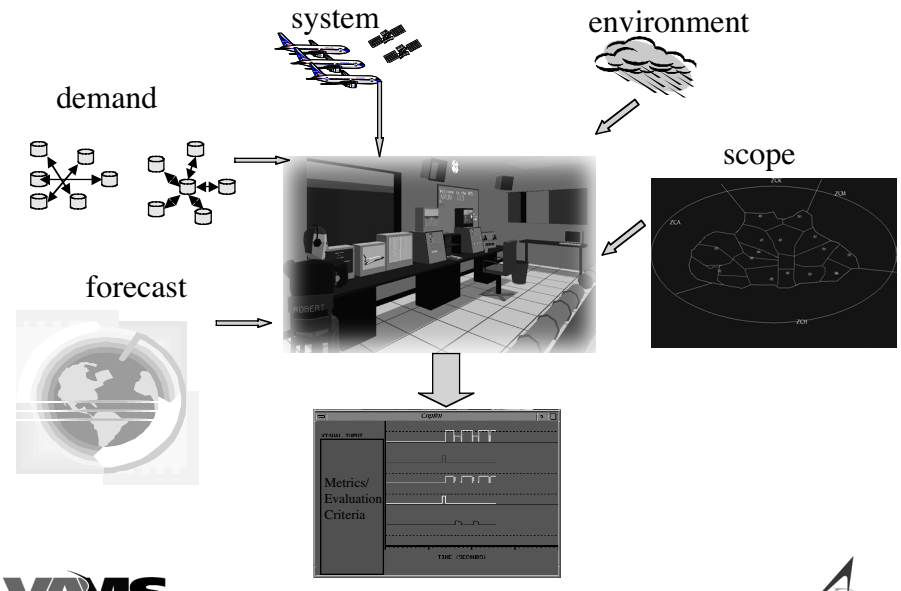
Scenarios/Metrics

- Scenarios and Metrics will be used to help evaluate the concepts from VAMS/System Level Integrated Concepts
  - Initial evaluation of concepts will be self-evaluation
  - The scenarios/metrics for self-evaluation can be used to assist the SEA scenario/metric development
- There can be many scenarios and metrics, but ultimately they must be applicable for broad evaluations
  - Scenarios addressing multiple airspace domain and concepts addressing more specific domains
  - Scenarios addressing multiple parts of the triad (AOC/ATC/FD)

Scenario Requirements

- Scenarios are necessary for the evaluation of the "capacity-increasing" concepts
- Scenarios must test the concepts' ability to increase capacity and maintain (or increase) safety
- Scenarios must cover all domains (e.g., surface, terminal, enroute)
- Scenarios must consider normal and non-normal events
- Scenarios must cover real-time and fast-time testing
- Scenarios must test all parts of the NAS triad: AOC, ATC, flight deck
- Scenarios must be able to test both single-domain concepts and more broad concepts
- SEA is writing the requirements for the scenarios

Scenario Parameters within SEA



Some Scenario/Metric Parameters

Forecast	Demand	System	Environment	Scope
Economic Activity	Number of Airports	Aircraft Characteristics	Weather	Whole v. part of NAS
Energy Availability	Fleet mix	Airport Characteristics	Safety Situations • Operational errors • Reduced Landing Capacity • Aircraft/Vehicle On the Runway	Fidelity of the Scenario
War and pestilence	Load factor	Airspace Characteristics	Failures	Temporal Resolution
Environmental Concerns	Schedule	CNS Infrastructure	Security Situations	Simulation Timing/ Synchronization
Demographics	Origination/ Destination Pair	NAS Architecture		
Travel Confidence		Humans		

Note: Assume a multiple-day schedule of flights for these scenarios

Framework for Scenario & Metrics Development*

Stakeholder Viewpoints (questions to be answered)

Stakeholder Viewpoints (questions to be answered)

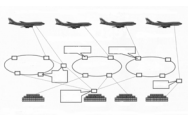
concepts → operational scenarios → NAS Model → output metrics → evaluation metrics

1. Scope:
•issues
•NAS Domain
•challenges
•assumptions

2. Top Level Descriptions:
•core ideas
•functions

3. Detailed Descriptions:
•performance
•roles, responsibilities
•@ humans & machine
•human factors
•user interfaces

4. NAS infrastructure & technology impacts:
•transition planning
•architecture
•technology requirements



Scenario Elements:
•NAS Domain
•NAS Perturbations (e.g. Wx, Security Incidents)
•Origin/Destination Demand
•Assumed Technologies
•Human/Machine Performance
•Defined ATM Procedures
•Assumed Equipage
•Fleet Mix
•Etc.

Simulations

Empiric Analysis

•Number of traffic events (takeoffs, sector crossings, landings, etc.)
•Number of communication events (requests, clearances, directives, etc.)
•throughput (traffic volume)
•Delay
•Safety incidents (proximity to minimum separation, incursions, encroachments, etc.)
•Elapsed flight times
•Fuel burn
•Capital investments
•Personnel workloads
•Etc.

•Average aircraft flight time per air route*
•Average aircraft payload per flight mile
•Operational cost per passenger mile
•Average taxi time from pushback to wheels up during peak traffic periods per specific airports or taxi paths within airports
•Average voice channel occupancy time per departure from pushback to take off
•Average Airport arrival rate during peak periods
•Rate of arrivals per controller hour per airport
•Aircraft (or engine, or other component) maintenance costs per flight mile
•Etc.

* a defined city pair air route

*Viewgraph from Jack Perkins, Volpe Center

Breakout Sessions

- Metrics & deliverables – Apples to apples may not be possible given the wide range of concepts and their relative maturities. A completely level playing field may not be possible.
- If it can't demonstrate capacity increase, it's out.
- Scenarios & metrics are to evaluate concepts, not particular technologies or models.
  - ♦ Data, look like a lot, but the list of archived items is "short". But a lot of information is never recorded = unavailable.
    - Self-evaluation will help data definition to evolve – larger set of folk coming up with ideas enhances variability.

Breakout Sessions

- Capacity limiting bumpers need to be considered (e.g., wake-vortex separation, runways) as bounds to the models - Some exist.
- SEA provides the definition of the scenarios (inputs, outputs, considerations) to the VAST sub-element to ensure tool evaluation is good and back to the concept developers to tweak/enrich the concept set.
- How does the data create the world of the future?
- Common terminology is important – Project office has developed & will distribute a lexicon.

Breakout Sessions

- Levels of parameters
  Must be broad enough to not put unnecessary limits on the concepts
- Detail
  Important to specify terms – VAMS lexicon is available
- Range/distribution of parameters may be more important than using averages
- Some items belong in multiple categories
- Specify fixed and variable categories
  Some disagreement about which categories can be left to the concepts to define, which should be defined by the project
- Objectives –metrics –parameters
- Required performance v. required capabilities

Breakout Sessions

- Fast and real-time scenarios
  - ♦ When to use them
- Demand split into 2 categories
  - ♦ Passengers/cargo (SEA defined)
  - ♦ Airlines/resources/choice of mode (Concept defined)

Breakout Sessions

- Focus – Passenger focus (door-to-door) is program or project level? VAMS focuses on gate to gate. VAMS feeds upward into door-to-door level model.
- How does international traffic impact hubs? There are significant traffic volumes at some airports; e.g., 15% at LAX. Ignoring it gives skewed answers.
- How do we handle the possible mismatch between the concepts v. evolving NAS tools?
- War & Pestilence
  - Does it reduce overall traffic? Military carriers may be up, especially US initiated international flights.
  - These are shocks to the "normal" situation. Feel that "shocks" have to be addressed. How big are the shocks; e.g., Sept 11 total shutdown? Feeling is that Sept 11 is out of scope, but still TBD.

Breakout Sessions

- Normal vs. abnormal – concern that out-of-normal may overwhelm scenario mix.
  - Will individual modelers have to account for all common scenarios and factors or will they get to choose Chinese-menu style (risky).
  - How frequent and how long?
    - Frequency is important
    - We won't be making up data where it doesn't exist
  - Abnormal situations are harder to validate. Data exist for bad whether in the summertime. Data don't exist for many of the shock factors.
  - But leaving it to the end may result in many "unanswered questions"
- Weather has data and highest frequency. It's the "normal / abnormal" situation.

Breakout Sessions

- Primary stakeholders drive the prioritization
- Scenario – what constitutes it, how do we create it, how do we measure it?
  - ♦ Storyboard approach – same process for all scenarios -- has worked in one environment. Same process helps consistency.
  - ♦ Working on what will be delivered – requirements and storyboard – for both fast time & real time
    - Coming up, hopefully shortly after the TIM
  - ♦ Policy (e.g., 100% X-ray) may impact scenarios
    - Maybe specifics of policy appear in each of the 5 categories

Breakout Sessions

- Airline proprietary data
  - ♦ Wait until it becomes an issue and then attack it
  - ♦ "Genericize" it for use in scenarios
- Document the faults and limitations of each of the data sets. If don't do it, then the analysis will be compromised.
- Passengers are taxpayers (owners)

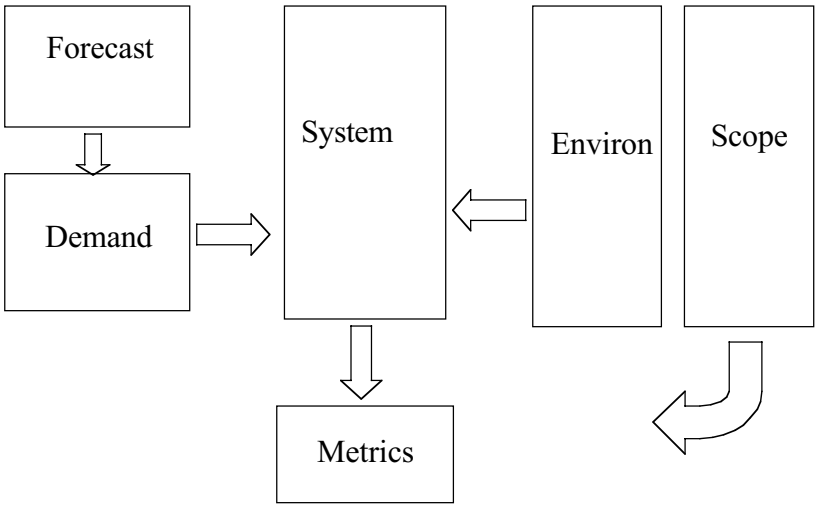
Breakout Sessions

- Consensus is that Human Factors should not be a separate category.
  - ♦ Humans provide both key capabilities and key limitations to the system and must be part of the system
  - ♦ Both need to be reflected in the scenarios and models.
  - ♦ Remember that humans "change the task" when they become overworked. Don't tackle a concept that is impossible for humans to use.

Breakout Sessions

- How do we address technology change in the system category?
  - ♦ The cycles are getting shorter in the marketplace.
  - ♦ There are automation and training.
- 20 year forecast in the Program Office. Are we going to develop scenarios for intermediate points; e.g., 10 & 15 years, too?
- Common scenarios are coming from VAST.
  - ♦ Individual activities will provide building block scenarios for the common scenarios (to be distributed back to the individual activities) & used in a "kludged format".
  - ♦ What happens after this TIM?

Breakout Sessions

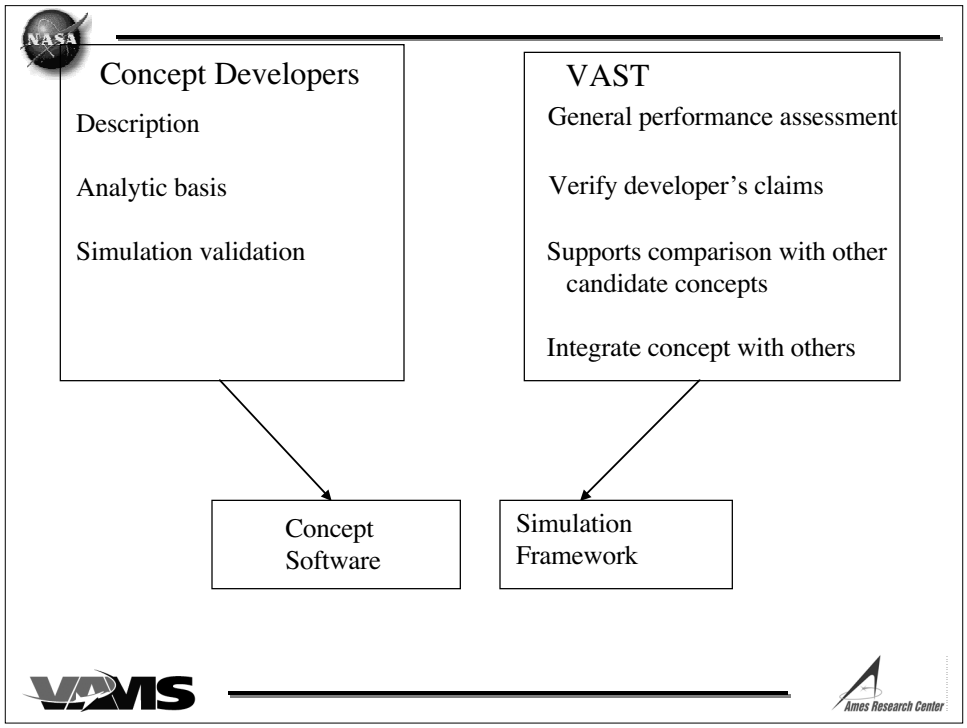


Development of Modeling & Simulation Capability Driven by Concepts

Len Tobias
NASA Ames Research Center
VAMS TIM #2
August 27, 2002

What will be discussed

- Not: What will be needed to completely evaluate all the proposed concepts?
- Rather: What is the most effective means of letting the concepts drive the modeling and simulation development?



Outline

- Review of selected concept proposals
- Modeling and simulation requirements based on the concepts
- Issues: given finite time, staff and $, how should we proceed?
- Guidelines for selecting what to address

Summary of System Level Concepts

- All Weather Maximum Capacity Concept (Metron):
  - Weather reduces capacity. Prediction of weather (e.g., winds aloft, gusts, icing, turbulence, fog) will improve. This in itself can improve the ATM planning process. But we can also develop dynamic optimized routing procedures to handle weather-related problems more effectively.

Summary of System Level Concepts (2)

- Massive Point-to-Point (PTP) & On-Demand Air Transportation System Investigation (Seagull):
  - The hub and spoke system is congested. Use the over 5000 under-utilized public airports to provide PTP operations, which will avoid hubs whenever possible. Some key characteristics of this will be: on-demand operations, greater ATM automation and flexible routing.

Summary of System Level Concepts (3)

- Air Transportation System Capacity-Increasing Concepts Research Proposal (Boeing):
  - The existing constraint set limits capacity. However, by 2010, three key elements (National Flow Management, Common Information Network and Common Information Base) will have been implemented. Use these elements to eliminate existing constraints.

Summary of System Level Concepts (4)

- Concepts for System-wide Optimization (NASA):
  - For the present system, use existing rerouting schemes (e.g., Playbook) and optimize flow rate to meet demand. For future systems, develop fully optimal routing.

Summary of Domain-Specific Concepts

- Capacity Improvements Through Automated Surface Traffic Control (Surface; Metron):
  - Use automation to generate clearances based upon complete, conflict-free airport surface paths. Communicate clearances to pilots via control of runway lighting. The assumption is that there will be multiple data sources (ARTS, ASDE-X, ADS-B) available and multiple advisory concepts (AMASS, SMS) operational.

Summary of Domain-Specific Concepts (2)

- Surface Operation Automated Research (SOAR) (Surface; Optimal Synthesis):
  - Start with a ground-control automation system (GO-SAFE) and an FMS-based aircraft clearance system for precision taxi (FARGO). Use these to build a tightly integrated automation system for surface operations.

Summary of Domain-Specific Concepts (3)

- Centralized Terminal Operation Control (CTOC) (Terminal; Northrop Grumman):
  - Analogous to the Maritime Industry's Harbor Pilot, the concept proposes remote control of aircraft in the terminal domain as a means of addressing current spacing inefficiencies of today's terminal operations. Pilots and controllers can assume control for safety/security reasons.

Summary of Domain-Specific Concepts (4)

- Terminal Area Capacity Enhancement Concept (TACEC) (Terminal; Raytheon):
  - Blend the following capabilities to increase the capacity of terminal area operations: airborne self-separation, 4D, complex final approaches and others. The assumption is there will be improved surveillance, reliable/secure data link, enhanced weather prediction capability.

Summary of Domain-Specific Concepts (5)

- Advanced Airspace Concept (Enroute; NASA):
  - An automation system to generate efficient, conflict-free clearances and send them to aircraft via data link. The system is backed by a safety net (TSAFE) which monitors clearances and conformance.

What Modeling & Simulation Needs to Address

- Existing ATM Framework
  - Aircraft
  - ATC
  - System Command Center
  - Airline Operations Center
  - System operations
    - Capacity, delays
    - Sector & route structures
    - Planning
    - Equipage
    - Constraints

What Modeling & Simulation Needs to Address (cont.)

- Innovations
  - CNS Technology
  - Broader access to information
  - Distributed management
  - Flexibility
  - Automation
- Impacts
  - Safety
  - Security
  - Environment

Issues for Simulating Capacity Concepts

- General
  - What is a concept?
    - What isn't a concept
    - Level of specificity
    - How "imperfections" are addressed
  - What is capacity?
    - 3X: is it worth simulating?
    - Capacity vs. cost

Issues for Simulating Capacity Concepts (2)

- Evaluation
  - What is the desired approach in evaluating system-wide concepts vs. domain specific concepts?
  - How do we select what to simulate?
    - Number of concepts
    - Commonality of features
    - Concepts which require facilities we need to develop
    - Concepts for which specific impact is critical

Issues for Simulating Capacity Concepts (3)

- Evaluation (continued)
  - How do we design the simulation environment?
    - Selection of sites
    - Assumptions about future systems
    - Consistency of fast and real time simulation
  - How do concepts need to interact with each other and with the simulation environment?
    - Concepts additive or in competition?
    - Integration of concepts into the real time system
  - Specific evaluation issues

Suggested Guidelines on How to Use Concepts to Drive the Modeling & Simulation Development

- Build capability which incorporates features common to many concepts (improved weather prediction, flexible routes and sectors, common information network), but focus should be errors, deviations, abnormalities
- Limit details of models for system-wide concepts to address broad questions)
- Evaluate & compare two domain-specific concepts
- Integrate two concepts
- Evaluate one concept's impact on security, safety or environment
- Develop issue-driven AOC & SCC models

Concept Portrayal Response: The Developers Turn

Kevin James
NASA Ames Research Center
August 27, 2002

Outline

- 3-5 Minutes Position Clarification by each of the Principle Investigators
- General Discussion to follow, given any remaining time

Terminal Area Capacity Enhancement Concept

TACEC

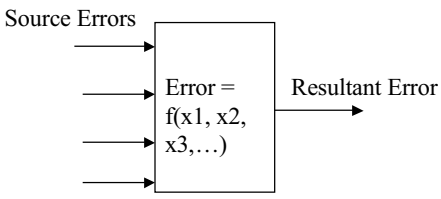
Modeling Requirements

August 22, 2002

C³I / C³S

Modeling Approach

- **Start with lowest-level fidelity model of all functions needed to evaluate concept**
  - **Breadth vs Depth**
  - **Increase fidelity in later phases as evaluation warrants**
  - **Model effects of the enabling technology. For example, WAAS resultant position/velocity errors instead of explicit models of GPS Constellation, Ground Stations, Avionics, etc**
  - **Include primary error contributors**
    - **Errors may be initially constant (but tuneable) and then dependent upon current condition (weather, flight geometry, etc) as simulation matures**



Evaluation requires Realism

Raytheon
C³I / C³S

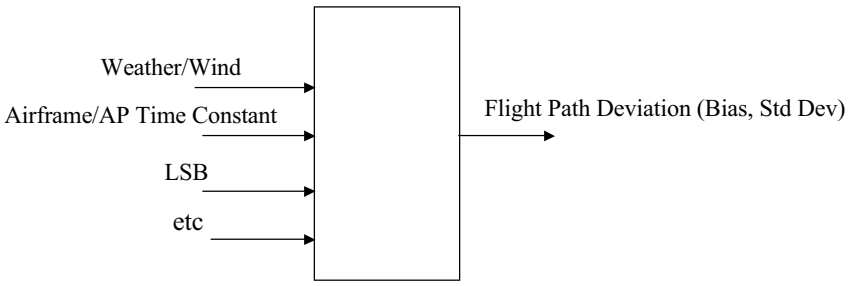
- **Perfect CNS and FMS**
  - **Aircraft Truth State (ATS) = Commanded Flight Path (CFP)**
- **Simulation must include realistic errors of enabling CNS and FMS technologies to evaluate concept feasibility**
  - **1) Add FMS errors (ability to maintain flight path)**
    - » **ATS = CFP + FMS Flight Path Deviation**
  - **2) Add Navigation/Tracking errors (knowledge of own aircraft position)**
    - » **Aircraft Sensed State (ASS) = ATS + Tracking Errors**
  - **3) Add Surveillance/Comm errors (reporting of own aircraft position)**
    - » **Aircraft Reported State (ARS) = ASS + Reporting Errors**

FMS Error Model

Raytheon
C³I / C³S

1) Ability to maintain commanded flight/surface path

- **Add Flight Path Deviation to Commanded path to generate Aircraft Truth State**

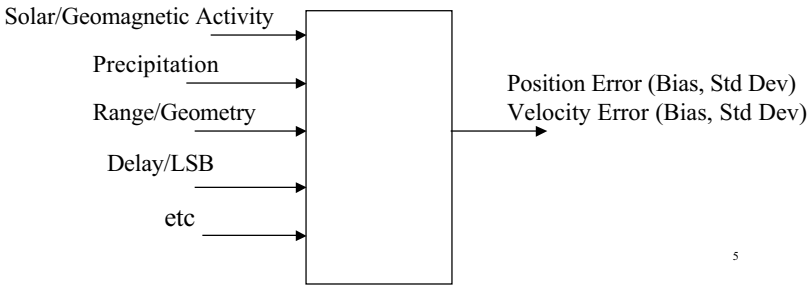


Navigation/Tracking Error Model

C³I / C³S

2) Knowledge of own aircraft position via selected technology (GPS/WAAS, GPS/LAAS, ILS, Primary Radar, ASDE-X, etc)

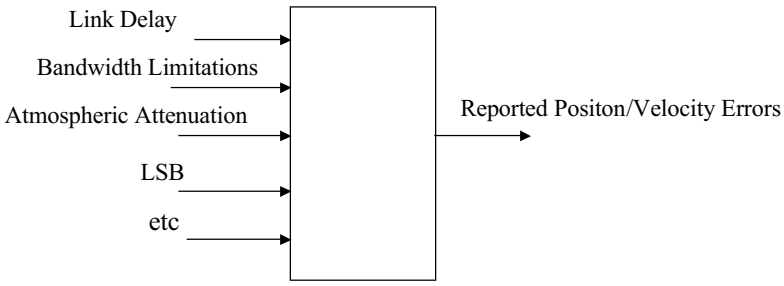
- » **Include Noise and Bias Errors with values based on selected tracking technology**
- » **Add Resultant Tracking Errors to Aircraft Truth State**



Surveillance/Comm Error Model

C³I / C³S

3) Reporting position of own Aircraft to Ground Controllers and/or other Aircraft via selected technology (ADS-B, Mode 6)



Ground-based Operational Algorithm Models

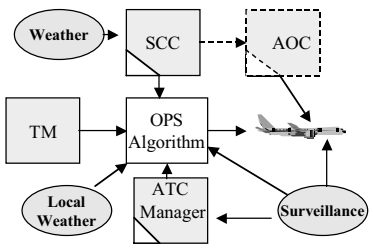
Raytheon
C³I / C³S

- TACEC Operational Algorithms to be included in simulation
  - Terminal Airspace
    - » 4D Curvilinear Flight Path w/Wake Vortex & Weather Avoidance
  - Surface
    - » Runway/Taxiway Optimal Path
- Inputs to Operational Algorithms, with increased fidelity as simulation matures
  - SLIC Phase 2 requires low fidelity models of
    - » Reported Aircraft State, Wake Vortex, Wind, Convective Weather, Surface/Gate Status

Ground/Air Collaboration

Raytheon
C³I / C³S

- Model of ground manager/flight crew interfaces needed to evaluate flight path collaboration, separation, and conflict avoidance advisories
- TACEC requires low fidelity models of functional elements and data links depicted below in SLIC Phase 2



Surface Environment

Raytheon
C³I / C³S

- **Model of Airport Infrastructure and Integrated Terminal Area Network needed to evaluate Surface Automation**
  - **Initially leaning toward an Analytical Model of the Surface Environment**
    - » **Parameters such as aircraft type, arrival/departure speed, arrival/departure runway occupancy time, position uncertainty, wind speed, communication delay, passenger load/unload, pre-trip security, gate availability, de-icing, etc will need to be included**
    - » **If further analysis indicates an Analytical Model will not satisfy evaluation, a true simulated model with detailed representation of airport infrastructure and operations will be required**

Wake Vortex Model

Raytheon
C³I / C³S

- **As a primary constraint on Arrival Rate, Wake Vortex (WV) is needed to evaluate Terminal concepts**
- **SLIC Phase 2, WV may be modeled as a constant (tuneable) dimension around a point source aircraft based on existing WV separation requirements**
  - **4D Trajectory Algorithm based on constant separation**
- **SLIC Phase 3, include WV movement due to wind**
  - **Include Wake Vortex Advisory System effects by adding errors on actual WV position. 4D Trajectory Algorithm uses predicted WV position.**

Weather Model

C³I / C³S

- Weather phenomenon impacting air transportation include, winds, turbulence, thunderstorms, hail, micro bursts, downdrafts, fog, and ice
- TACEC requires in SLIC Phase 2
  - » Atmospheric Winds to evaluate flight path control
  - » Convective weather to evaluate weather avoidance
  - – Additional models in SLIC Phase 3
    - » Ice and Fog to evaluate effects on surface ops
- Weather Forecast data needed by ground managers and flight crew

Noise/Pollution Model

C³I / C³S

- Noise is a primary constraint on Airport Capacity
  - – TACEC requires in SLIC Phase 2 a noise model such as Metron's Noise Impact Routing System (NIRS) to evaluate terminal flight paths
- Aircraft emissions have a significant impact on environment
  - – TACEC requires an emissions model in SLIC Phase 3 to evaluate arrival/departure and surface procedures that will save fuel and reduce emissions

Recommended PTP Primary Components for VAST Modeling

- **Door-to-door (e.g., multi-modal modeling)**
- **Small airport automation**
- **Terminal airspace design/impacts (utilizing the 5400+ airports)**
- **Increased flight network connectivity (e.g., greater use of PTP vs. HS)**
- **Conflict free (aircraft, Wx, wakes) 4D precision trajectories**
- **DSTs (optimal trajectory planning, CDM, TFM, AOC Precision Control Toolbox)**
- **Dynamic sectors & sectorless flight levels**
- **Self-separation**
- **Mixed equipage**
- **CNS (ADS-B, FMS, TIS-B, CPDLC, LAAS, WAAS)**

PTP VAST Modeling Unique Needs/Issues

- **Door-to-door (e.g., multi-modal modeling)**
  - **Primary impact for the cost model**
- **Small airport automation**
  - **Cost models need to address life cycle costs of non-towered sensors and ground automation and new avionics**
  - **What will be the allowed throughput?**
- **Terminal airspace design/impacts**
  - **Analysis is required to optimize each terminal area (i.e. they are all unique!)**
  - **Terminal land features are fixed, e.g. runway location, relative location to other airports**
  - **Need to take into account local (i.e., not just itinerant) traffic operations as loading on smaller airports.**
- **Increased flight network connectivity (e.g., greater use of PTP vs. HS)**
  - **5400+ airports with a network to each other (e.g. no dog legs).**
- **Precision Control Toolbox**
  - **Provides AOC the ability to adjust arrival times**
- **DSTs (optimal trajectory planning, AOC Collaboration)**
  - **AOC has pre flight objectives as well as in flight. AOC will negotiate with ATSP for optimal/neighboring optimal trajectory.**
- **Dynamic and Sectorless airspace**
  - **New sectorless airspace, centralized monitoring, operational impacts**
  - **Dynamic based upon workload (accounts for complexity)**

General VAST Modeling Issues

- **All concepts (not just PTP) need higher 2020 traffic level-based demand with expected fleet mix changes (e.g., greater frequency of smaller commuter/air taxi flights)**
- **Lots of Concept PTP functions exist (some overlapping with other concepts); how to deal with overlap between aspects of our concept and others?; blending sooner or later?**
- **Need to get VAST functionality with deep enough level of fidelity to represent details of new concept focus (e.g., anchor points); tradeoff of fidelity with scope**

GFI Model	VAMS Required Functionality	Boeing	Metron - Weather	Seagull	AMES - Sridhar	Metron - Surface	Optmal Synthesis	Northrup-Grumman	Raytheon	Langley - Rutishuser	AMES - Erzberger	University
Nat Traffic Mgmt	"5400 Airport" System Model			x								
	Full Trajectory Conflict Avoidance	x		x	x							x
	High/Low Density Regions	x										x
	On-Demand Ops			x								
	Sector and Sectorless Ops		x	x	x						x	x
	Sequential Trajectory Planning				x							
	Weather Avoidance Algorithms		x	x	x							
Local Traff Mgmt	4D Terminal Path Alg - groundbased			x				x	x		x	x
	ATSP/Weather Displays		x									
	Blunder Reconginition Time					x						
	Curvilinear final flight paths								x			
	New Decision Support Tools		x	x			x	x	x		x	
	Surface Automation		x			x			x			
	Surface Automation via Controllers					x						
	Surface Automation via FMS					x	x		x			
	Surface Automation via lights					x						
	Surface Automation via Pilots					x	x					
	Surface Automation via timed routes						x					
	Surface Deceleration Control Alg.						x		x			
	TCAS		x								x	
	Terminal FP Alg. Monitored by Specialist							x				
	Tower Monitors/Surface Displays					x	x		x			
	TSAFE										x	
	Wake Vortex Avoidance Alg.								x	x		
	Weather Avoidance Algorithms		x	x					x			
	Wind Optimal Routing		x		x				x			
	Workload - Controller						x	x	x		x	
CD&R & SA	Full Trajectory Conflict Avoidance	x		x	x			x	x		x	x
	Surface						x					
Flight Plan/Collab	Collaborative Flight Planning			x			x		x		x	x
	Collaborative Arrival/Departure							x	x			
Traff Cont & Adv	Conflict Avoidance Advisories							x	x		x	
	Override to FlightPath by ATC							x	x			
	Separation Assurance Advisories							x	x		x	
Adj Air Traff Fac												
CNS/Weather	ADS-B		x	x		x	x		x		x	x
	ASDE-X					x	x		x			
	Datalink		x	x				x	x		x	x
	GPS		x			x			x		x	
	ILS		x				x					
	Increased VHF Safety								x			x
	Integrated Terminal Area Network								x			
	LAAS		x	x			x		x			
	Mode-S		x						x		x	
	Multi-sensor Surface Surveillance fusion					x			x			
	NASWIS			x								
	NEXCOM Digital Radio		x									

GFI Model	VAMS Required Functionality	Boeing	Metron - Weather	Seagull	AMES - Sridhar	Metron - Surface	Optmal Synthesis	Northrup-Grumman	Raytheon	Langley - Rutishuser	AMES - Erzberger	University
	Position/Velocity Uncertainty		x	x		x						
	Redundant Ground Nav System			x								
	Stochastic Weather				x							
	UHF/VHF - Voice Comms		x	x							x	
	WAAS		x	x		x			x			
	Wake Vortex					x			x	x		
	Weather		x	x		x			x	x		
	Weather Exposure		x									
	Weather Sensing/Prediction		x	x		x			x	x		
Aircraft Control	4D FMS Terminal		x	x				x	x		x	x
	Aircraft Self Separation	x		x					x			x
	Missed Approaches							x	x			
	Override to Terminal Flightpath by Pilot							x	x			
	Workload - Crew						x	x	x			
Airframe	FD/Weather Displays		x									
	FMS/Datalink/CDTI Equipped Aircraft	x		x			x	x	x		x	x
	Smaller/Varied Aircraft			x								
Land/Intermod	Door-to-Door Transportation			x								x
	Street-side								x			x
Term Cargo/Sec	Passenger Load/Unload					x						x
	Pre-trip Security			x								x
Airspace	Modified Enroute Sectors			x							x	
	Modified TMA			x								
	Modified TRACON			x					x			
	Tube Concept											x
Rules/Proc/Stnds	Separation Standards							x	x			
AP Runways, etc	Airport Lighting			x		x						
	Average Queuing Time (surface)					x			x			
	De-Icing					x			x			
	Gate Availability					x			x			
	Gate Maintenance					x						
	Non-Towered Airport ATM			x								
	Ramp								x			
	Runway Configuration					x	x		x			
	Runway Incursions					x			x			
	Runway Occupancy					x		x	x			
	Runway Occupancy Charge											x
	Small/Regional Airports			x								x
	Surface Congestion					x						
	Taxi-in Time					x						
	Taxi-out Time					x						
NAS Mgmt	Airspace Auctioned											x
	Traffic Demand Model for 2020			x								
Design Consid.	Cost - Direct Operating		x			x			x			

GFI Model	VAMS Required Functionality	Boeing	Metron - Weather	Seagull	AMES - Sridhar	Metron - Surface	Optmal Synthesis	Northrup-Grumman	Raytheon	Langley - Rutishuser	AMES - Erzberger	University
	Cost - Provider, System, User			x					x			
	Cost - Terminal Area							x	x			
	Noise		x			x			x			
	Pollution		x			x			x			
	Stochastic SUA				x							
AOC	Optimal Origin/Destination Flight Paths			x					x			

	Concept Developer	Raytheon					
	SLIC Phase		2	3	4A	4B	See Slide
GFI Model	**VAMS Required Functionality**						
Nat Traffic Mgmt	"5400 Airport" System Model						
	Full Trajectory Conflict Avoidance						
	High/Low Density Regions						
	On-Demand Ops						
	Sector and Sectorless Ops						
	Sequential Trajectory Planning						
	Weather Avoidance Algorithms						
Local Traff Mgmt	4D Terminal Path Alg - groundbased	x	L	M	H		7
	ATSP/Weather Displays						
	Blunder Reconginition Time						
	Curvilinear final flight paths	x	L	M			7
	New Decision Support Tools	x	L	M	H		
	Surface Automation	x	L	M	H		7, 9
	Surface Automation via Controllers						
	Surface Automation via FMS	x	L	M	H		7,9
	Surface Automation via lights						
	Surface Automation via Pilots						
	Surface Automation via timed routes						
	Surface Deceleration Control Alg.	x	L	M	H		7,9
	TCAS						
	Terminal FP Alg. Monitored by Specialist						
	Tower Monitors/Surface Displays	x			L		
	TSAFE						
	Wake Vortex Avoidance Alg.	x	L	M	H		7,10
	Weather Avoidance Algorithms	x	L	M	H		7,11
	Wind Optimal Routing	x		L			
	Workload - Controller	x		L	M		
CD&R & SA	Full Trajectory Conflict Avoidance	x	L	M	H		8
	Surface						
Flight Plan/Collab	Collaborative Flight Planning	x	L	M	H		8
	Collaborative Arrival/Departure	x	L	M	H		8
Traff Cont & Adv	Conflict Avoidance Advisories	x	L	M	H		8
	Override to FlightPath by ATC	x	L	M	H		8
	Separation Assurance Advisories	x	L	M	H		8
Adj Air Traff Fac							
CNS/Weather							
Communication	Generic Surv/Comm Errors		L	M			6
	VHF/UHF Datalink	x		L	M	H	
	UHF/VHF - Voice Comms						
	NEXCOM Digital Radio						
	Integrated Terminal Area Network	x	L	M	H		
	Increased VHF Safety						
	NASWIS						
Navigation	Generic Nav/Tracking Errors		L	M			5
	GPS Constellation/Surv Errors	x	I	L		M	
	GPS Redundant Ground System						
	LAAS	x	I				
	GPS (see above)						

	Concept Developer	Raytheon					
	Correction Algorithms/Msg Content			L			
	VHF Datalink (see above)						
	Ground-based Transmitter						
	Atmospheric Attenuation (see above)						
	Aircraft Avionics (see Airframe below)						
	WAAS	x	I				
	GPS (see above)						
	Wide Area Ground Reference Stations			I			
	Wide Area Master Stations/Processing			L			
	Correction Message			L			
	Ground Uplink Station			I			
	GEO Satellites			L		M	
	Aircraft Avionics (see Airframe below)						
	Atmospheric Attenuation (see above)						
	ILS						
Surveillance	Generic Surv/Comm Error	x	L	M			6
	ADS-B	x	I	L		M	
	GPS (see above)						
	1090ES datalink (commercial aviation)			L		M	
	UAT link (general aviation)			L		M	
	1Hz surv - reduced sep via ATC			L			
	Air/Air surv & alerting - self sep			L	M		
	Flight path intent, low fuel alert, etc			L			
	Atmospheric Attenuation		I	L		M	
	Aircraft Avionics (see Airframe below)						
	ASDE-X	x	I	L	M	H	
	Radar/Surv Errors		I	L		M	
	Collision Alert/AMASS		L	M	H		
	Mode-S	x	I				
	Surveillance radar (beacon)			L		M	
	Aircraft Transponder			L		M	
	Ground-based signal processing			L			
	Digital Datalink - air-to-air			L		M	
	Digital Datalink - ground-air-ground			L		M	
	Message Content (incl weather?)			L	M	H	
	Cockpit Display (CDTI? - see Airframe)						
	Atmospheric Attenuation (see above)						
	Multi-sensor Surface Surveillance fusion	x					
Weather	Stochastic Weather						
	Wake Vortex	x	L	M	H		10
	Weather	x	L	M	H		11
	Weather Exposure						
	Weather Sensing/Prediction	x	L	M	H		11
	ITWS, Enroute?						
Aircraft Control	4D FMS Terminal	x	L	M	H		4
	Aircraft Self Separation	x	L	M	H		8
	Missed Approaches	x		L	M	H	
	Override to Terminal Flightpath by Pilot	x		L	M	H	
	Workload - Crew	x		L	M	H	
Airframe	FD/Weather Displays						
	FMS/Datalink/CDTI Equipped Aircraft	x	I	L		M	4,6
	Smaller/Varied Aircraft						
Land/Intermod	Door-to-Door Transportation						
	Street-side	x	L	M	H		9

	Concept Developer	Raytheon					
Term Cargo/Sec	Passenger Load/Unload						
	Pre-trip Security						
Airspace	Modified Enroute Sectors						
	Modified TMA						
	Modified TRACON	x	L	M	H		
	Tube Concept						
Rules/Proc/Stnds	Separation Standards	x	L	M	H		
AP Runways, etc	Airport Lighting						
	Average Queuing Time (surface)	x	L	M	H		9
	De-Icing	x		M	H		9,11
	Gate Availability	x	L	M	H		9
	Gate Maintenance						
	Non-Towered Airport ATM						
	Ramp	x	L	M	H		9
	Runway Configuration	x	L	M	H		9
	Runway Incursions	x	L	M	H		9
	Runway Occupancy	x	L	M	H		9
	Runway Occupancy Charge						
	Small/Regional Airports						
	Surface Congestion	x	L	M	H		9
	Taxi-in Time	x	L	M	H		9
	Taxi-out Time	x	L	M	H		9
NAS Mgmt	Airspace Auctioned						
	Traffic Demand Model for 2020						
Design Consid.	Cost - Direct Operating	x	L			M	
	Cost - Provider, System, User	x	L			M	
	Cost - Terminal Area	x	L			M	
	Noise	x	L	M	H		12
	Pollution	x		L	M	H	12
	Stochastic SUA						
AOC	Optimal Origin/Destination Flight Paths	x	L	M	H		

Fidelity implies a level of detail and accuracy that provides the required functionality in a model.

Key	Description	Definition
L	Low Fidelity Model	Model that exhibits the functionality necessary for the simulation system to consistently portray the NAS for the primary research objectives in a high-level manner.
M	Medium Fidelity Model	Model that exhibits the functionality necessary for the simulation system to consistently portray the NAS for primary research objectives, infrastructure sensitivity analysis, and cost/benefit analysis.
H	High Fidelity Model	Model that exhibits the functionality necessary for the simulation system to consistently portray the NAS for secondary level research objectives, infrastructure sensitivity analysis, and cost/benefit analysis.
I	Implicit modeling	Specifically relates to the software construct. If not a discrete software component, the effects of a related or dependent model may be developed implicitly as part of a model. From the logical perspective, the implicit model may be represented internally, however only its meaningful effects will be represented outside of the larger software component.

Eval Tools	SLIC/ACES Timelines	End of Phase
	ACES Phase 2	Nov-02
N/A	SLIC Phase 1	Feb-03
	ACES Phase 3	Oct-03
Avail VAST	SLIC Phase 2	Feb-04
	ACES Phase 4	Jul-04
Initial VAST	SLIC Phase 3	Feb-05
Exp VAST	SLIC Phase 4A	Jan-06
Full VAST	SLIC Phase 4B	May-07

VAST Requirements

Tom Romer
VAST Lead
NASA Ames Research Center

VAMS TIM #2
Moffett Training and Conference Center
August 27, 2002

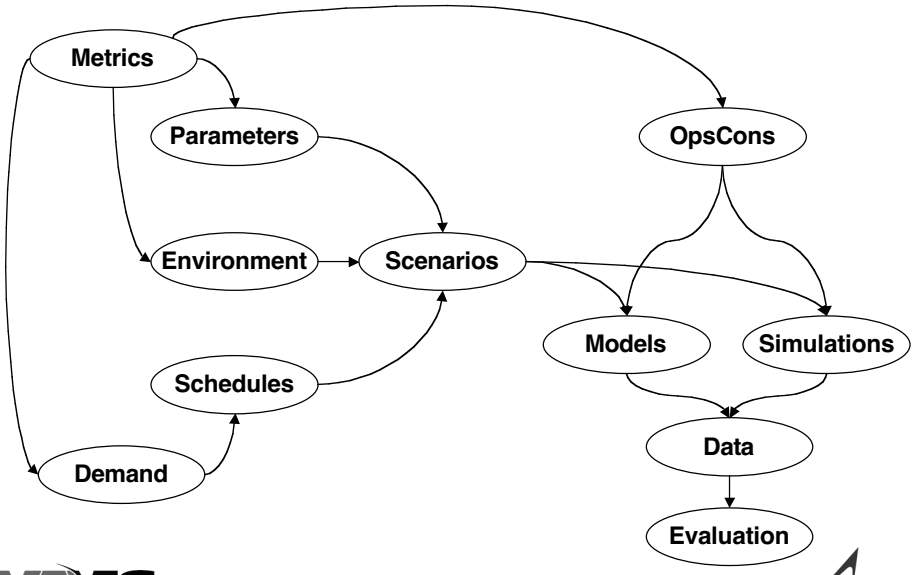
Outline

- **Requirements Definition Process**
- **Requirements Approach**
- **Deliverables**
- **Challenges in VAST requirements**
- **Questions**
- **Overview of tomorrow's sessions**

Requirements Definition Process

- **Establish Metrics (SEA)**
  - Parameters and required data sets
- **Define Scenarios (SEA)**
  - Common Scenario Set
- **Define Operational Concepts (SLIC)**
  - Concept functionality
- **Map Concepts to Concept Functional Model (SLIC)**
  - Concept integration and models
- **Define VAST architecture and functionality (VAST)**
  - Functionality resulting from scope of effort

Simplified Requirements Flow



Requirements Approach

- **Issues contrary to "perfect world" process**
  - Project Phasing
  - The "chicken or egg" syndrome
  - Many unknowns
  - Many approaches
  - Many undefined elements
- **Parallel Artifact Development**
  - Establishing metrics and scenarios
  - Defining and maturing concepts
  - Developing modeling and simulation systems
- **Consequences**
  - Many assumptions are made
  - Will never have everything as wanted when needed
  - Integration is minimal at first but improves with time

VAST Requirements Approach - 1

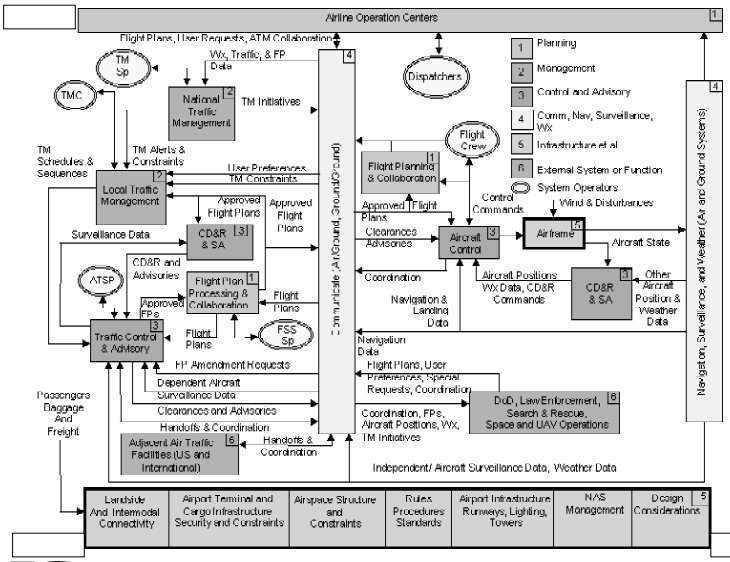
- **Establish initial requirements**
  - Scope Efforts (fast-time, real-time)
  - Survey other modeling and simulation systems
  - Understand deficiencies in current/past capabilities
- **Define what is needed**
  - Flexible, extendable, reconfigurable systems
  - Distributed environments
  - Stepped functionality improvements
- **Know what is missing**
  - Described future concepts
  - Full set of metrics
- **Early Decisions Made**
  - Use current NAS (2002) to define initial development
  - Create independent scenarios and validation plan

VAST Requirements Approach - 2

- **Next Steps (short-term)**
  - Begin integrating additional requirements from growing knowledge base
    - **Maturing VAMS Concepts**
    - **Refining Metrics and Scenarios**

- **VAMS Concepts help define future requirements**
  - Review current information on concepts to establish modeling requirements (VAST/SLIC)
  - Interview concept developers for guidance and feedback (VAST/SLIC)
  - Gather information through mechanisms like TIMs (VAMS)
  - Map concepts to Concept Functional Model (SLIC)
  - Extract VAST requirements from Concept Functional Model (VAST)
  - Prioritize VAST development efforts (VAMS)
  - Integrate prioritized requirements as required (VAST)

Concept Functional Model



Concept Mapping

NRA GFI Model	VAMS Required Functionality (for planning purposes only)	Initial Requirements	Model Developer or Coder for ACES and/or RTHITL	VAST / COR Code required (Y/blk)	Real-Time Functionality	Non-Real-Time Functionality	Comment Number	Potential Simulation object type (model = called function, algorithm = logic tree, adaptation = a unique representation of the model)	CONCEPTS: VAMS Blending Concept	Boeing	Metron - Weather	Seagull	AMES - Sridhar	Metron - Surface	Optimal Synthesis	Northrup-Grumman	Raytheon	Langley - Rutishauser	AMES - Erzberger	University	"X" count	Other: DAG	FAA's CEF functionality	NAS Concept (RTCA 4.1)	Eurocontrol Concept	ICAO ERAFT Concept	VAST: Prototype	Build 1	Build 2	Build 3	Build 4	SCENARIOS: National Good Wx day 1	National Good Wx day 2	National Bad Wx day 1	National Bad Wx day 2	High Alt Facility Down	Terminal Facility Down	Runway Down	Regional Comm Down	Security Contingency
Nat Traffic Mgmt	"5400 Airport" System Model	Seagull																			1																			
7	Full Trajectory Conflict Avoidance									x			x	x						x	4																			
	High/Low Density Regions									x										x	2																			
	On-Demand Operations	Seagull											x								1																			
	Sector and Sectorless Operations										x	x	x	x						x	x	5																			
	Sequential Trajectory Planning	Ames												x								1																			
	Weather Avoidance Algorithms										x	x	x									3																			
Local Traff Mgmt	4D Terminal Path Alg - groundbased												x						x	x	x	x	5																		
20	ATSP/Weather Displays	Metron										x										1																			
	Blunder Recognition Time	Metron													x							1																			
	Curvilinear final flight paths	Raytheon																	x			1																			
	New Decision Support Tools											x	x			x	x			x		5																			
	Surface Automation											x			x				x			3																			
	Surface Automation via Controllers	Metron													x							1																			
	Surface Automation via FMS														x	x						2																			
	Surface Automation via lights	Metron													x							1																			
	Surface Automation via Pilots														x	x						2																			
	Surface Automation via timed routes	OS														x						1																			
	Surface Deceleration Control Algorithm	OS														x						1																			
	TCAS											x								x		2																			
	Terminal FP Alg. Monitored by Specialist	NG															x					1																			
	Tower Monitors/Surface Displays														x	x						2																			
	TSAFE	Ames																		x		1																			
	Wake Vortex Avoidance Alg.	Langley																	x			1																			
	Weather Avoidance Algorithms											x	x									2																			
	Wind Optimal Routing											x		x								2																			
	Workload - Controller																x	x		x		3																			
CD&R & SA	Full Trajectory Conflict Avoidance										x			x	x			x	x	x	x	7																			
2	Surface CD&R & Separation Assurance	OS																x				1																			
Flight Plan/Collab	Collaborative Flight Planning													x			x		x	x	x	5																			
2	Collaborative Arrival/Departure	NG															x					1																			
Traff Cont & Adv	Conflict Avoidance Advisories																	x		x		2																			
3	Override to FlightPath by ATC	NG																x				1																			
	Separation Assurance Advisories																	x		x		2																			
Adj Air Traff Fac																						0																			
0																						0																			
CNS/Weather	ADS-B										x	x			x	x		x	x	x	x	7																			
15	ASDE-X														x	x		x				3																			
	Datalink										x	x							x	x	x	6																			
	GPS										x				x				x		x	4																			
	ILS	Metron									x					x						2																			
	Increased VHF Safety	Univ																			x	1																			
	Integrated Terminal Area Network																		x			1																			
	LAAS										x	x					x		x			4																			
	Mode-S										x								x		x	3																			
	Multi-sensor Surface Surveillance fusion														x				x			2																			
	NASWIS	Seagull											x									1																			
	NEXCOM Digital Radio	Metron										x										1																			
	Position/Velocity Uncertainty											x	x			x						3																			
	Redundant Ground Nav System	Seagull											x									1																			
	Stochastic Weather	Ames												x								1																			

VAST Requirements Approach - 3

- **Metrics & Scenarios help define future requirements**
  - Review concept developers' scenarios and metrics (SLIC/SEA/VAST)
  - Extract information from metrics list and description of common scenario set and evaluation criteria (VAST/SEA)
  - Review real-time system validation experiment requirements (VAST/SEA)

ACES Deliverables

- **Build 1**
  - Capabilities: Overall emphasis on architecture and run-time capability, establishing core architectural foundation and initial set of models for toolkit. Integrate and develop basic simulation control, data collection and visualization. Target ability to assess economic impact of new technology and NAS operational performance, and the ability to model the dynamic effects of interactive agents.
  - Delivery Date: December 2002
  - Requirements Defined by: May 2002 (completed)
  - Concept modeled: Current NAS (2002)
  - Scenario: Simulate a good-weather day-in-the-NAS. NAS-wide, gate-to-gate simulation. Emphasize TFM interactions (ATCSCC/ATSPs/AOCs). En route ATC. Simple terminal/airport ATC models. Mixed fidelity AC.
  - Metrics: Flight time delay. Departure delay. Fuel costs. Controller workload measures (# of vectors given, speed changes...).

ACES Deliverables

- **Build 2**
  - Capabilities: Emphasis on performance and expanded modeling. Enhance the core architectural foundation. Expand set of models for model toolkit (fidelity for current NAS models/VAMS new concepts?). Enhance simulation control, data collection and visualization. Target ability to model and assess uncertainty within the system and within models, to model infrastructure and transitory constraints and assess their impact on the system.
  - Delivery Date: December 2003
  - Requirements Defined by: September 2002
  - Concept modeled: Defined when requirements are available
  - Scenario: Defined when requirements are available
  - Metrics: Defined when requirements are available

ACES Deliverables

- **Build 3**
  - Capabilities: Emphasis on usability and expanded modeling. Expand on set of models for model toolkit (fidelity for current NAS models/VAMS new concepts, cognitive human performance, CNS). Enhance simulation control, data collection and visualization. Target expanding models to higher resolution levels.
  - Delivery Date: August 2004
  - Requirements Defined by: September 2003
  - Concept modeled: Defined when requirements are available
  - Scenario: Defined when requirements are available
  - Metrics: Defined when requirements are available

ACES Deliverables

- **Build 4**
  - Capabilities: Target ability to support trade studies of VAMS operational concepts.
  - Delivery Date: September 2005
  - Requirements Defined by: June 2004
  - Concept modeled: VAMS operational concepts
  - Scenario: Common Scenario Set
  - Metrics: VAMS defined metrics

Real-Time Deliverables

- **Preliminary Design**
  - Capabilities: Define initial requirements, preliminary design and development plan. Define major elements of the simulation environment. Describe preliminary interface specifications. Define initial gaps in current real-time simulation capabilities.
  - Delivery Date: September 2002
  - Requirements Defined by: June 2002 (completed)
  - Concept modeled: NA
  - Scenario: NA
  - Metrics: NA

Real-Time Deliverables

- **Complete Design**
  - Capabilities: Refine and complete requirements from the preliminary design. Prioritize requirements to meet the needs of the baseline validation experiment. Initialize development of system through prototyping.
  - Delivery Date: June 2003
  - Requirements Defined by: December 2002
  - Concept modeled: Current NAS (2002)
  - Scenario: Pilots and controllers fly and control aircraft in the terminal area with some self-spacing tasks using CDTI and self-spacing algorithms. Crews will land the aircraft and both flight deck and ATC will use surface management tools.
  - Metrics: Defined when needs are stated

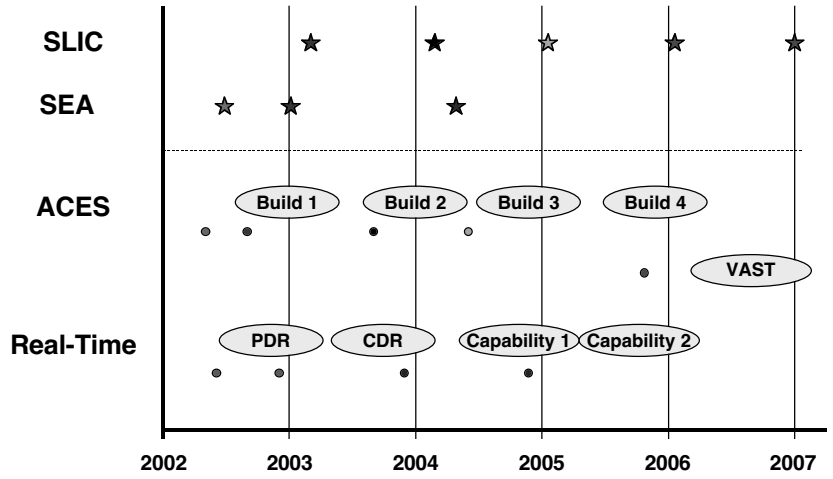
Real-Time Deliverables

- **Capability 1**
  - Capabilities: Overall emphasis on developing architecture and integrating initial real-time models, simulator labs and facilities into the run-time capability. Execute a defined human-in-the-loop experiment for system design validation.
  - Delivery Date: September 2004
  - Requirements Defined by: December 2003
  - Concept modeled: Current NAS (2002)
  - Scenario: Pilots and controllers fly and control aircraft in the terminal area with some self-spacing tasks using CDTI and self-spacing algorithms. Crews will land the aircraft and both flight deck and ATC will use surface management tools.
  - Metrics: Defined when needs are stated

Real-Time Deliverables

- **Capability 2**
  - Capabilities: Enhance architecture and expand network capability to support multi-facility experiments. Expand set of real-time models. Expand facility interfaces. Execute a defined human-in-the-loop experiment for system design validation.
  - Delivery Date: June 2005
  - Requirements Defined by: September 2004
  - Concept modeled: Defined when requirements are available
  - Scenario: Defined when requirements are available
  - Metrics: Defined when requirements are available

VAMS Deliverables



Challenges in VAST Requirements

- Synchronizing VAST requirements needs with VAST development timeline.
- Ensuring appropriate VAST capabilities are available to concept developers and evaluators when needed.
- Providing and integrating all models necessary for the evaluation of all concepts.
- Leveraging modeling and simulation capabilities from other efforts (When to develop ourselves? When to acquire?).
- Selecting appropriate time scale (fast-time or real-time) for acquiring given metrics.
- Understanding the use of real-time simulation as part of the concept design phase.

Questions - 1

- **Questions for VAST to answer**
  - What capabilities will VAST have?
  - When will these capabilities be available?
  - How will the necessary models be developed and integrated?
  - What development support will be available?
  - What operational support will be provided?
  - When would fast-time or real-time simulation be applied?
  - Will some models and capabilities be reusable in both fast-time and real-time domains?

Questions - 2

- **Questions for SLIC to answer**
  - Who defines the elements of the concept functional model not addressed by domain specific concepts?
  - Will concept developers be able to specify, develop and validate concept specific models for integration into VAST?
  - Will concept developers/evaluators have resources to learn and use VAST capabilities?
  - Will interim information be available from concept developers between specific contract deliverables?

Questions - 3

- **Questions for SEA to answer**
  - Will concept evaluators have resources to learn and use VAST capabilities?
  - Will concept specific scenarios and metrics beyond the common scenario set and metrics be considered for evaluation?
  - Will these additional items be applied to all other concepts?

Overview of Task Sessions

- **ACES**
  - Overview envisioned non-real-time capabilities
    - Modeling details, data flow, validation plan
- **Real-Time**
  - Overview of preliminary design
- **Human/Team Performance Modeling**
  - Envisioned cognitive modeling
- **CNS Modeling**
  - Envisioned CNS modeling

NASA Langley Research Center

Systems Analysis Branch

Air Transportation System Engineering & Analysis

August 27, 2002

Sam Dollyhigh
Gary Millsaps
Swales Aerospace/LaRC

System-level Assessment of Operational Concepts, Technologies, and New Vehicles in the National Airspace System

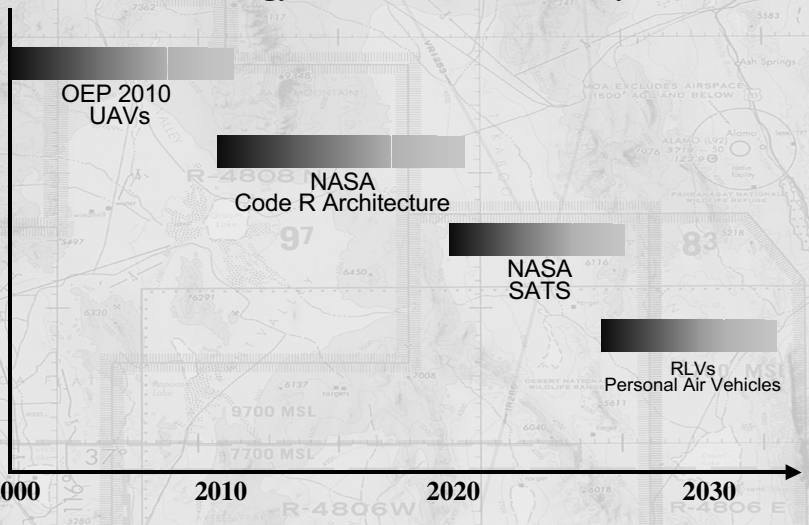
- Framework for integrated systems analysis/engineering of air transportation system safety, capacity, economics, and environment
- Advanced aviation concepts/technology impacts on the integrated aviation system
  - Technical performance
  - Cost effectiveness
- New operational concepts and technologies with defined performance requirements that will have benefits across many scenarios
- Guidance on integration with and transition from current system to future system
- Technology investment portfolio guidance for best objective function solutions (e.g., risk, throughput, cost)
- Near, mid, and long-term time horizon

Programs, Organizations and Studies Supported

- Code R
  - Office of Aerospace Technology -- Investment Planning
    - Capacity and Mobility Goals
- Langley Research Center
  - Airborne Systems Competency
  - Small Aircraft Transportation System Program
  - Revolutionary Aerospace Systems Concepts Program
  - Safety Program
- Ames Research Center
  - Capacity Program
  - Virtual Airspace Modeling & Simulation Project

Virtual Airspace Modeling & Simulation – Technical Interchange Meeting #2

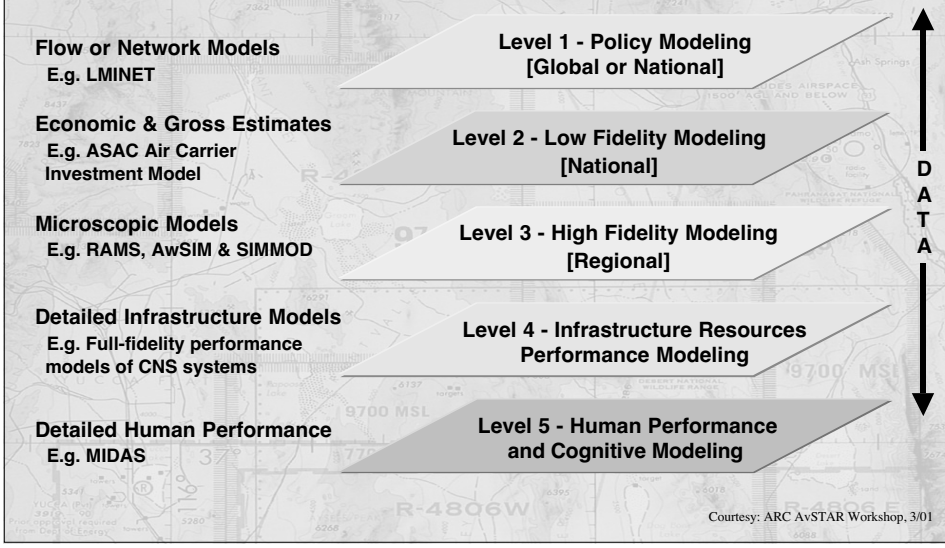
SAB ATS Engineering & Analysis
Technology Time Horizon for Analysis



Solution Space - System Engineering and Analysis Simulation & Analytical Tool Suite

- "Closed Loop" Performance Simulation
  - AwSIM/Aeralib - Aerospace Engineering & Research Assoc.
  - CNS&D/L - Draper Laboratory
- Future ATM Concepts Evaluation Tool (FACET) - ARC
- Post Operations Evaluation Tool (POET) - FAA, AUA-700
- Reorganized ATC Mathematical Simulator (RAMS) - ISA
- Aviation System Analysis Capability (ASAC) - NASA/LMI

An Integrated Suite of New and Legacy Models

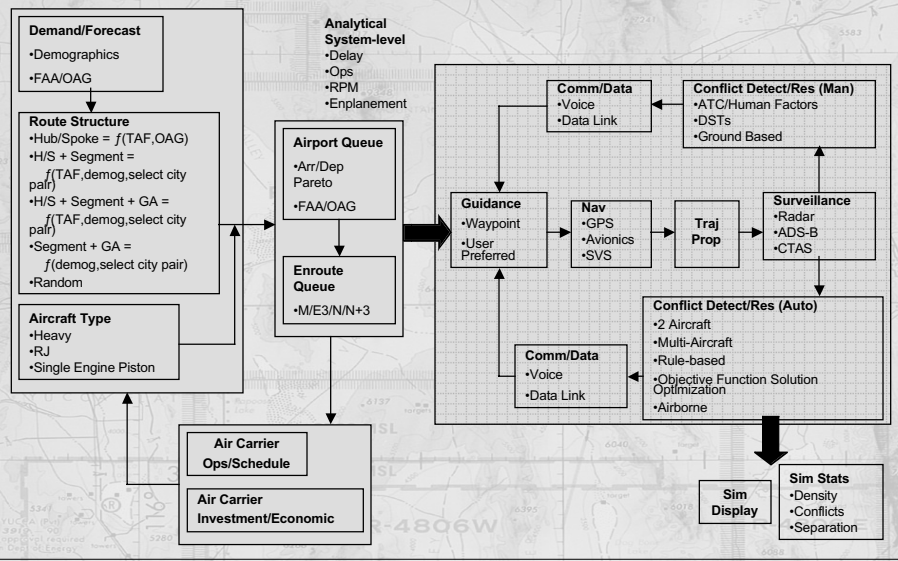


Courtesy: ARC AvSTAR Workshop, 3/01

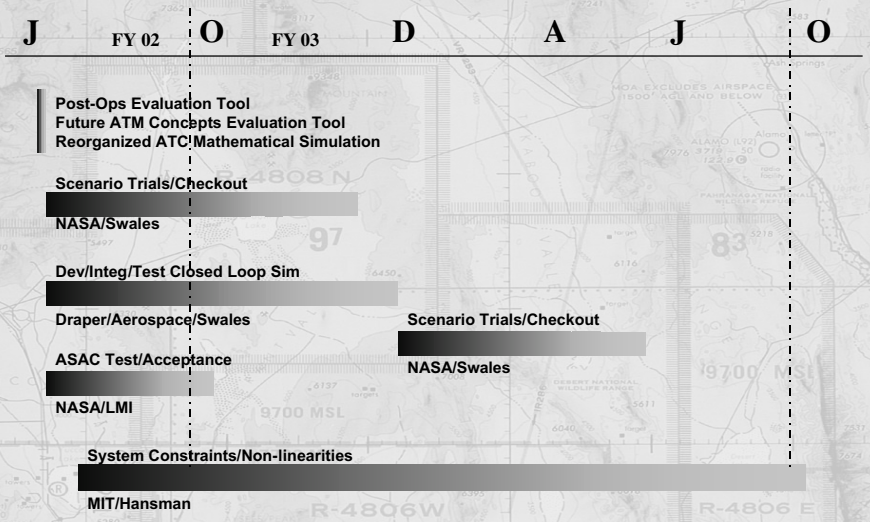
SAB ATS Engineering & Analysis Team Roles and Responsibilities

- **Systems Analysis Branch**
  - Economics, demand, route structures, and airport/national-level queue models
- **Swales Aerospace**
  - Overall simulation/model integration, operation and analytical support
- **Aerospace Engineering and Research Associates**
  - Flight/Trajectory simulation, Conflict Detection & Resolution, and statistics
- **Draper Laboratory**
  - Comm, Nav, Surveillance HW and Nav State simulation, airspace supply, and statistics
- **TeamVision**
  - Model integration framework, multivariable sensitivity analysis/display capability
- **MIT/International Center for Air Transportation**
  - Alternative concepts, key constraints, system non-linearity and dynamics, and decision making

SAB ATS Engineering and Analysis Simulation, Models, and Display



SAB ATS Engineering and Analysis Schedule



Virtual Airspace Modeling & Simulation – Technical Interchange Meeting #2

SAB ATS Engineering and Analysis Test & Validation

- ETMS/POET vs. AwSIM/Draper - Baseline
- DAG - TM 5
- DAG - TM 11
- Small Aircraft - Transition/Enroute

What's the Difference Between VAMS v. SAB Tasks?

- Beta test for VAMS
  - Subset of total VAMS scope
  - Work the details of tool/methods integration
  - Increase probability of VAMS success
- Total air transportation system analysis and impacts
  - Local/regional analyses
  - Rollup to system-level
- NASA in-house analysis line organization
  - Broad cross-section of customers and time horizons
  - Short term schedule needs
  - Multi-source funding leveraging

Virtual Airspace Modeling & Simulation – Technical Interchange Meeting #2

SAB ATS Engineering and Analysis
WakeVAS Analysis

- Methods
  - Previous Annual Goals Assessment of AVOSS technologies using ASAC airport/delay/enroute queuing models
  - Add simulation
    - RAMS – terminal/local
    - AwSIM/Draper -- transition/enroute/system
- Scenarios
  - Parallel and intersecting runways
  - Departures and arrivals
  - Dynamic spacing
  - Valid time horizon -- scheduled v. unscheduled usage
  - Multiple airports and OAG-based schedule/aircraft-type mix
  - Multiple environment and aerodynamic conditions
  - Boundaries/constraints of physical limitations

Solution Space -- System Engineering and Analysis Simulation & Analytical Components

- Demographic and FAA demand forecast
- Auto, Air Carrier and GA mode preference
- Origin & destination and route structure development
- Air transportation business, operations, and economics
- Terminal, enroute, and NAS capacity and delay
- NAS air traffic trajectory simulation
- Comm, navigation, surveillance and data infrastructure simulation
- Vehicle and air traffic management technologies and operations
- Multi-variable, sensitivity solution space analysis

Virtual Airspace Modeling & Simulation – Technical Interchange Meeting #2

Solution Space -- System Engineering and Analysis Functional Capabilities (e.g.)

- Integrated capacity, safety and economic tradeoffs
- Integrated local, regional & national NAS operations
- Performance impact of CNS, CDR & Data infrastructure components
- Non-controlled airport approach/departure scenario impacts
- Automated self-separation and self-sequencing
- GA/Air Carrier/Vertical Economics & Operations
- System requirements development and validation
- “Clean-sheet” traveler focused transportation system
- Multi-modal preference
- Integrated SATS/NAS flight demand and traffic assessment capabilities

Progress toward Developing & Validating the Airspace Concept Evaluation System

Dr. Karlin Roth
Chief, Aerospace Operations Modeling Office
NASA Ames Research Center

VAMS TIM #2
Moffett Training and Conference Center
August 28, 2002

Session Purpose

Objective: To provide potential users with the first in-depth look at the capabilities that are envisioned for the VAST non-real-time toolset.

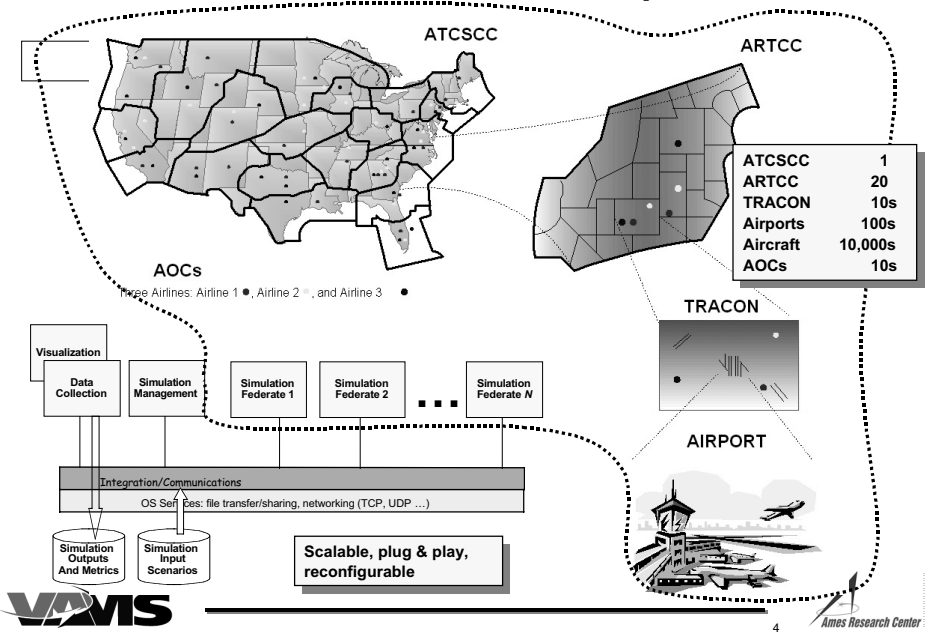
Outline

- Overview of the Airspace Concept Evaluation System (ACES) development plan
- Preparation of the simulation system for concept evaluation applications
- Detailed presentation of selected topics

Airspace Concept Evaluation System Development Plan

- **Demonstrated a proof-of-concept prototype 4/02**
  - **Selected the DoD's HLA-RTI infrastructure with agent-based software to enable fast-time NAS-wide simulation**
  - **Established a modeling lab that leverages existing and emerging models and tools**
- **Prove the feasibility of the approach to capture interactions between NAS entities (Build-1 System) 12/02**
  - **Integrate a suite of low-medium fidelity NAS models**
  - **Model dynamic effects of interactive agents**
  - **Assess NAS operational performance**
- **Enhance the modeling toolbox by adding functionality. 8/04**
  - **Develop and validate new models of NAS components**
  - **Increase model fidelity and simulation speed**
  - **Improve usability to enable technology transfer to airspace analysts**

Build-1 Simulation Description



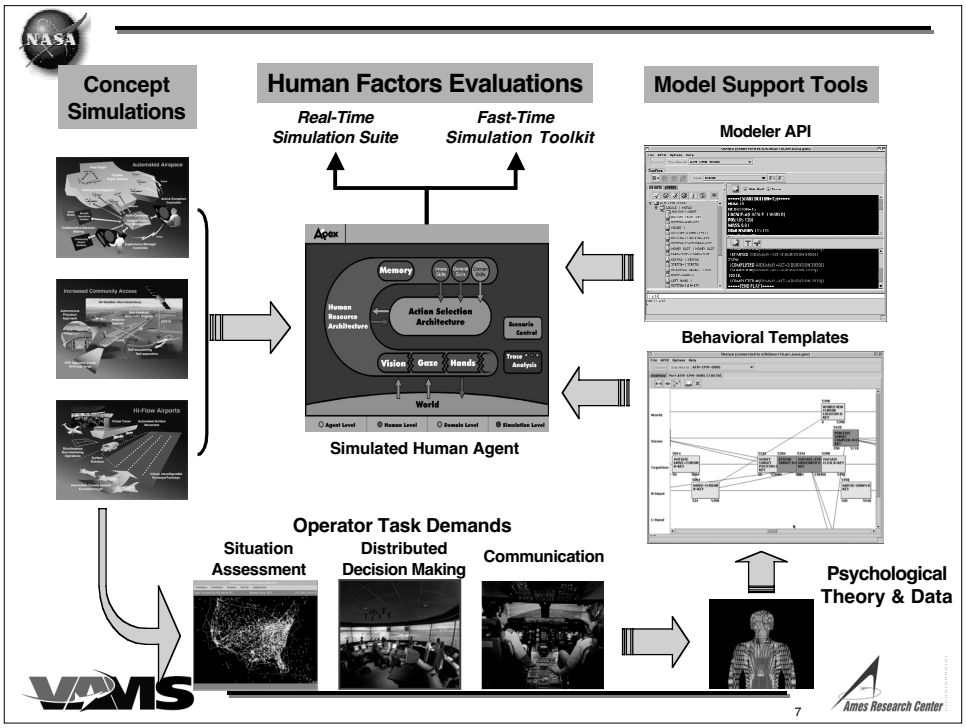
Topics for Detailed Discussion

- **Overview. . . . . (Doug Sweet)**
  - Terminology and Approach
  - Prototype
  - Build-1 Simulation System
- **Modeling Details. . . . . (George Hunter)**
  - Requirements
  - Implementation
- **Data flow. . . . . (Doug Sweet)**
  - Inputs
  - Outputs
- **Validation of Build-1. . . . . (Paul Abramson)**

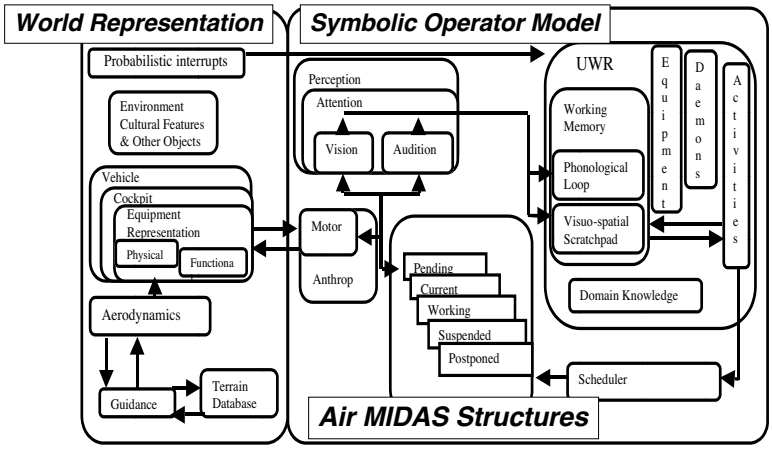
Enhancing the Modeling Toolbox

Several airspace modeling research activities support the growth of the Airspace Concept Evaluation System. Some examples are:

- Cognitive human performance modeling
  - Human/team performance model enhancements in APEX
  - Modeling of the Advanced Airspace Concept (NARI & SJSU)
- Probabilistic forecasting
- Environmental models - noise, emissions & wake vortex
- Validation of new and existing airspace models
  - Selection of datasets for a typical day (Metron Inc.)
  - Identification of critical parameters for model validation (GMU)



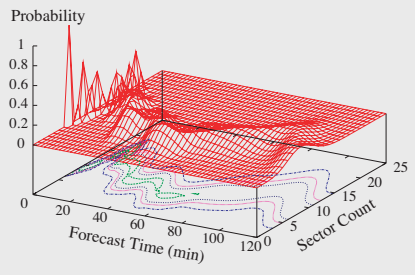
Evaluation of the Advanced Airspace Concept
from the Perspective of Human-System Integration



Integrate human performance models into the fast-time simulation environment and perform preliminary concept evaluation using methods proven in the Aviation Safety Program

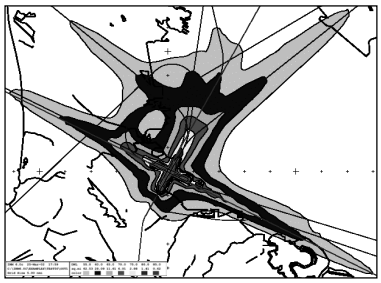
Probabilistic Modeling for Traffic Flow Management

- **Forecasting and Assessment**
  - Forecasting of Airport Delays
  - Fast-time simulation assessment of aircraft delay absorption strategies
- **Cooperative Research (MIT)**
  - Sophisticated AOC Model
  - Probabilistic Airport Capacities Model
- **Concept Evaluations in FACET**
  - Non-linear Estimation of Departure Times
  - Probabilistic Modeling of Monitor Alerts
  - Spatio-Temporal Measures for Congestion



Reference:
Meyn, L., "Probabilistic Methods for Air Traffic Demand Forecasting," AIAA 2002-4766, Aug. 2002

Integrated Noise Model (INM) Connected to Future Flight Central



Virtual Noise Office

Airspace Modeling Toolbox

Reference: Miraflor, R., "Requirements for Integrating a Noise Modeling Capability with Simulation Environments," AIAA 2002-5871, Oct. 2002.

Validation Methodology

- Adapt terms and practices from military simulation and computational fluid dynamics domains to airspace simulation
- Extend the evaluation of the fidelity of existing air transportation models to develop the range of critical parameters needed to validate new models (GMU)
- Provide scientific evaluation of NAS data to select suitable days for NAS-wide model validation (Metron Inc.)
  - Define and quantify statistical properties of the NAS during a 1-2 year timeframe
  - Identify "typical" days and "standard" days in the NAS

Basic Issues in Preparing the Simulation System for Concept Evaluations

- Need to define a specific, concept-driven focus for each ACES software build
- Need to define the ACES operational paradigm
  - User expertise requirement
  - System access (e.g. onsite or remote distributed access)
  - Development support (e.g. V&V and release management)
  - Operational support (e.g. maintenance)
- Need to clarify ACES role within VAMS Project
  - Interfaces/responsibilities across elements
  - VAST real-time and non-real-time roles

Concept-Driven Requirements

Quarter	ACES Deliverable	SLIC Deliverable
		Limited input from concepts to Build-2
4Q02	Build-2 requirements defined	Phase 1 Concepts & Scenarios
1Q03	Build-1 delivered for validation	Phase 1 Concept Roadmap
2Q03	*NASA in-house tests, development & analyses*	
3Q03		
4Q03		*Possible access to Build-1*
1Q04	Build-2 delivered for validation	Phase 2 Self-Eval by Concept Developers
2Q04		
3Q04		
4Q04	Build-3 delivered for validation	*Possible access to Build-2*
1Q05		Phase 3 Self-Eval by Concept Developers and Assessment of GFI toolbox & scenarios

Operational Assumptions

- ACES provides a common platform for system-level evaluation of SLIC concepts
- ACES provides a modeling infrastructure and incorporates features common to many concepts
- Concept developers need to provide validated, concept-specific models with appropriate detail for system-level analysis
- ACES will evaluate several, but not all, concepts as part of the tool development and validation process

ACES will grow as a research capability, not a production facility, during the 5-year VAMS Project

Near-Term Operational Considerations

- During 2003, tests will be conducted by NASA in-house users, assisted by software developers, to determine the application readiness of the simulation system
- NASA's onsite software development team is currently exploring the ease of model integration and co-development by linking FACET into the RTI
- Recommended procedures for ACES maintenance and support are being drafted
  - Initial access to ACES will be in NASA's Lab
  - Minimal support will be available during early releases

Introduction of Speakers

- Overview. . . . . (Doug Sweet)
  - Terminology and Approach
  - Prototype
  - Build-1 Simulation System
- Modeling Details. . . . . (George Hunter)
  - Requirements
  - Implementation
- Data flow. . . . . (Doug Sweet)
  - Inputs
  - Outputs
- Validation of Build-1. . . . . (Paul Abramson)

NASA AMES
Virtual Airspace Modeling and Simulation (VAMS)

Air Traffic Management System Development & Integration (ATMSDI)

VAMS TIM #2

Airspace Concepts Evaluation System: Overview

Douglas Sweet

28 August 2002

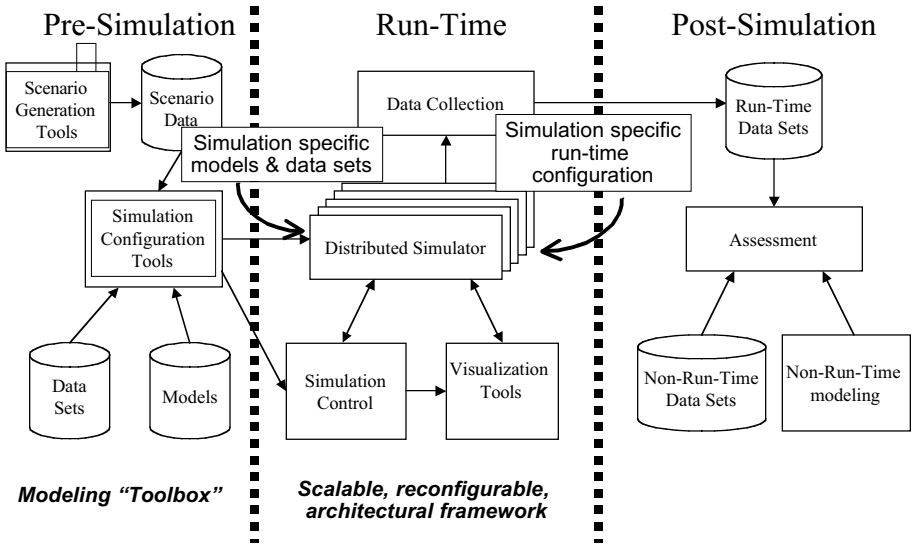
Outline

- **Overview**
  - System
  - Modeling
  - Architecture
- **Prototype System**
- **Build 1 System**

ACES Requirements

- **Represent interdependencies among NAS participants**
  - Current and future NAS is highly interactive
  - Requires NAS-wide simulation
- **Represent a wide variety of operational concepts**
  - New systems, new roles / responsibilities
  - Requires adaptable and flexible system
- **Provide broad assessment capabilities**
  - Operational, economic, and safety metrics
  - Requires models capable of producing a wide range of data
- **Provide a practical implementation approach**
  - Ease in developing and running a simulation
  - Ease in integrating new capabilities
  - Efficient use of computational resources
  - Requires tailored simulations using varying degrees of model fidelity

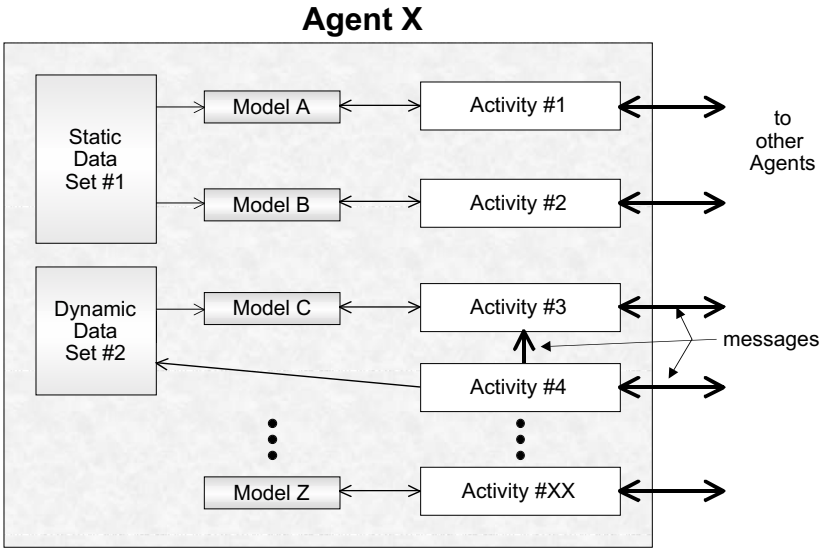
Airspace Concept Evaluation System



ACES Core Modeling Approach

- **Agent-based paradigm:**
  - Object oriented
  - each Agent made up of activities
  - each activity supported by individual models
  - Communication by messages
- **One-to-one correspondence to the NAS:**
  - Agents ⟹ NAS participants / entities
  - Activities ⟹ NAS participant's functions
  - Messages ⟹ NAS CNS systems
  - Data Sets ⟹ NAS environment
- **Multiple levels of model fidelity available**

Agent Example



ACES Core Modeling Approach

- **Agent examples:**
  - Aircraft: Flights, Pilots
  - Airline: Dispatchers, Ramp Managers
  - Air Traffic Control: ATCSCC, Sector Controllers, Traffic Management Units (TMU)
- **Activity examples:**
  - Flight: trajectory propagation, TCAS, Flight Management System
  - ATCSCC: Monitor Alert, Ground Delay Program, Ground Stop Program
  - Sector Controller: voice communications, conflict detection, conflict resolution, flight plan updates, hand-offs

ATMSDI CTO-07

ACES Core Modeling Approach

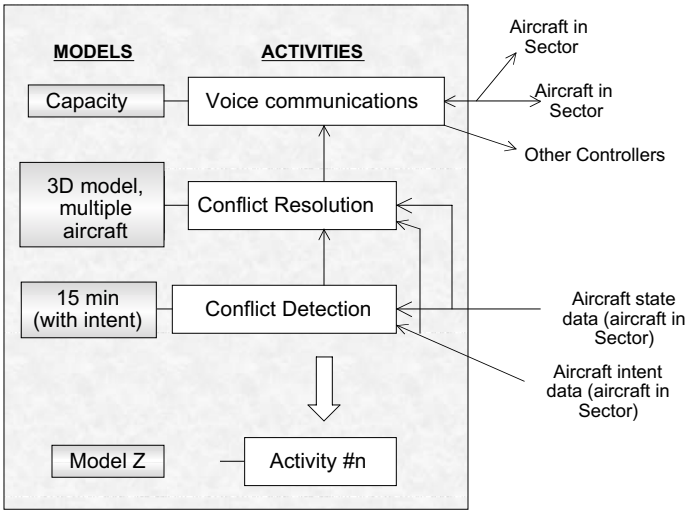
- **Agent to Agent message examples:**
  - Flight to Controller voice communication
  - Flight to Controller aircraft state data (radar-based)
  - Flight to Flight to Controller aircraft state and intent data (ADS-B)
- **Agent data set examples:**
  - Static (Airport locations, airspace definitions, facility boundaries)
  - Dynamic (winds, convective weather, dynamic facility boundaries)

ACES Core Modeling Approach

- **Multiple levels of model fidelity: examples**
  - **Flight trajectory propagation model**
    - » High fidelity - 4 DOF force model
    - » Medium fidelity - 3 DOF kinetic model
    - » Low fidelity - instantaneous acceleration
  - **Flight management system**
    - » High fidelity - FMS emulator
    - » Medium fidelity - airspeed, altitude, and route deviations
    - » Low fidelity - no trajectory deviation

Agent Example

Sector Controller Agent



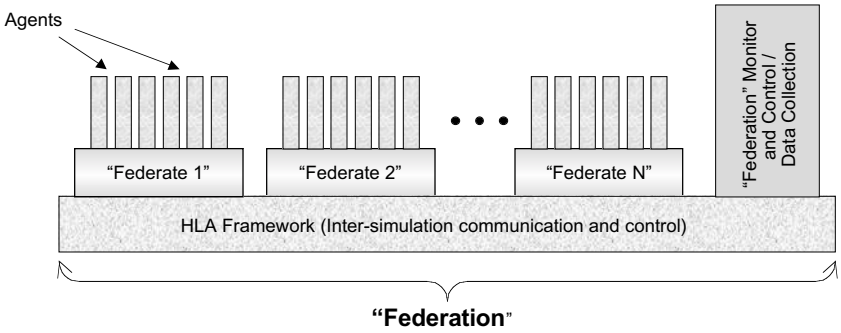
ACES Core Modeling Approach

- **Benefits**
  - One-to-one correspondence with NAS provides ability to isolate functionality
  - Modularity supports integration of new concepts
  - Supports flexibility in allocating Agents across the ACES distributed simulation framework

ACES Architectural Approach

Utilize High Level Architecture (HLA)

- Proven framework for large, distributed simulation
- Open architecture, widely used and supported
- Flexible and expandable



Federation Object Model (FOM) - specifies communication protocol between federates

Run-Time Infrastructure (RTI) - a communications infrastructure for federate to federate communication services

ACES Architectural Approach

Utilize an agent-based modeling and simulation engine:

Software layer between the agents and the HLA RTI

Supports intra-federate and inter-federate agent communication

Provides a well-defined modeling interface independent of the HLA implementation

model development independent of specific implementation

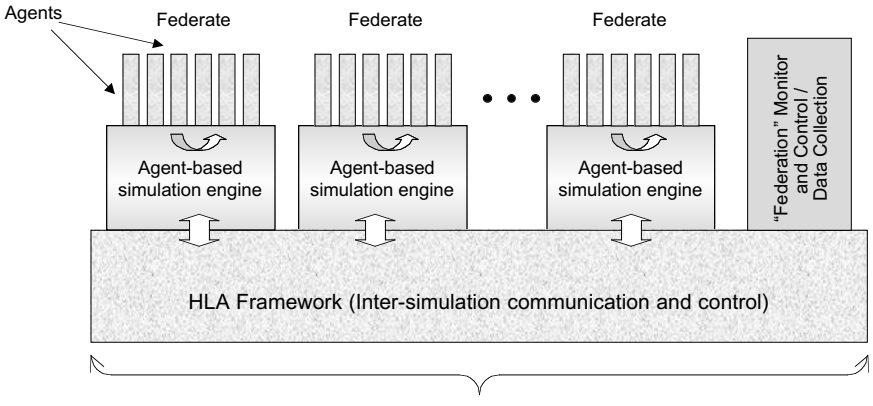
model development requires no knowledge of HLA

supports ease in allocating Agents for efficient utilization of computational and network resources

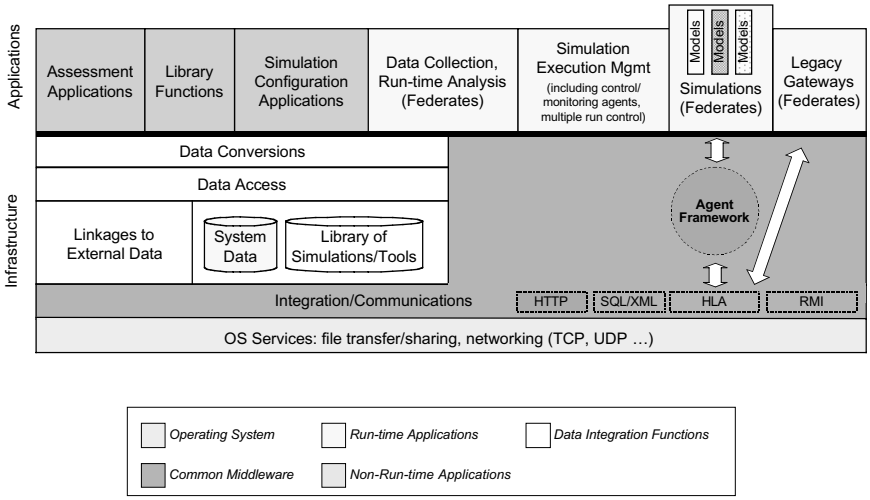
Provides a filtering mechanism to minimize HLA network traffic and improve overall performance

ACES Core Architectural Approach

- HLA provides Federate level flexibility / scalability
- Simulation Engine provides flexibility in allocation of Agents
- Allows the Agent to be the building block of the ACES simulation



ACES Overall Architecture



ACES Development

- **Prototype Demonstration System (completed)**
  - Demonstrate the use of HLA in a distributed, fast-time simulation
  - Demonstrate Agent-based modeling
- **Baseline System Development (in progress)**
  - Create a NAS-wide baseline simulation system
  - Validate the baseline system
- **System Enhancements**
  - Enhance Model Toolkit
  - Enhance architecture for performance / usability
  - Support VAMS concept evaluation and integration

ACES Development

- **Prototype Demonstration System (completed)**
  - Create a proof-of-concept system to demonstrate the use of HLA in a distributed, fast-time simulation
- **Baseline System Development (in progress)**
  - Create a NAS-wide baseline simulation system
  - Validate the baseline system
- **System Enhancements**
  - Enhance Model Toolkit
  - Enhance architecture for performance / usability
  - Support VAMS concept evaluation and integration

ACES Prototype Demonstration System

- **Transition agent-based, legacy simulation to HLA environment**
  - Utilize IAI's Agents-En-Route (AER)* NAS-wide simulation
  - Distribute AER agents into three separate "federates"
  - Integrate with HLA RTI, create FOM
- **Integrate centralized data collection and simulation control tools**
- **Extend modeling capabilities**
  - Incorporate "managed" aircraft paradigm (e.g. CD&R for sector controller, aircraft following an ETMS based flight plan)

. . . . . All in a four month period

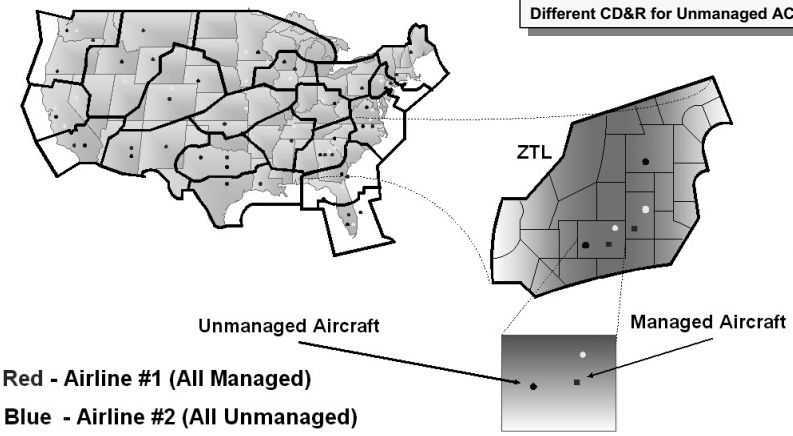
* developed under NASA SBIR, leveraging NASA's FACET simulation

Prototype: Simulation Description

NAS- Wide Enroute Simulation

Managed and Unmanaged AC in same airspace

Different CD&R for Unmanaged AC

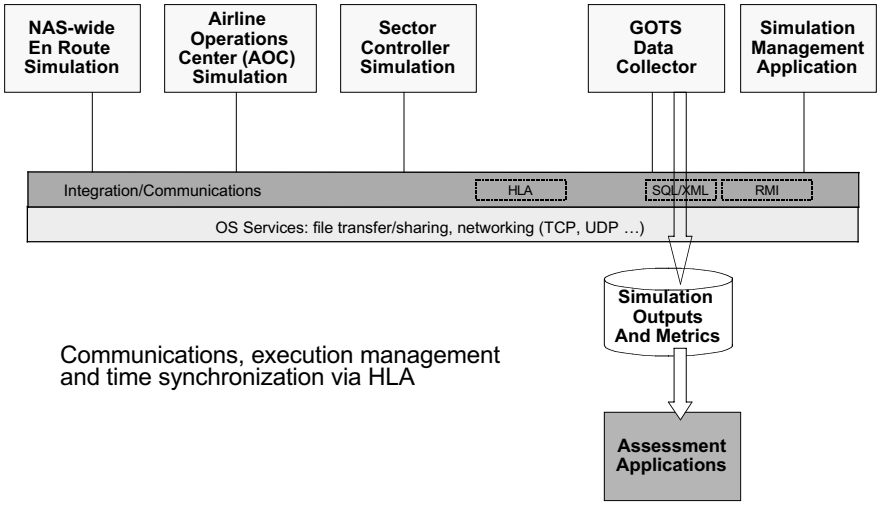


Red - Airline #1 (All Managed)

Blue - Airline #2 (All Unmanaged)

Yellow - Airline #3 (Mix Fleet)

Prototype Implementation



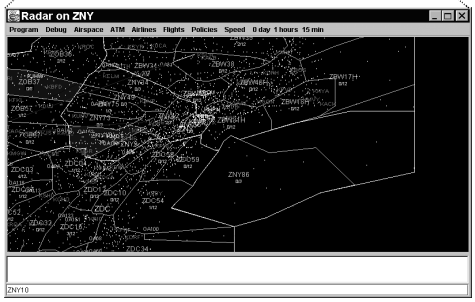
Communications, execution management and time synchronization via HLA

Prototype Configuration

Simulation Manager & Data Collection Federates

AER (En-Route Simulation) Federate

AOC & Controller Federates



Lessons Learned from Prototype

- **HLA-based architecture supported distributed simulations**
  - five interacting federates
- **Agent-based paradigm a good match for ACES**
  - provides clean interface to support efficient distribution of models in a distributed environment
  - supports ability to efficiently integrate new capabilities
- **Identified key needs for Build 1 system**
  - Need to incorporate HLA capabilities not utilized in prototype for improved performance
  - Need to support ease of model integration - Prototype modeler needed to understand HLA
  - Need to create foundation for ACES

ACES Build 1 System

- **Provide the architectural foundation**
  - **Create an agent infrastructure**
    - » modeler independence from HLA
    - » improved efficiency
    - » ease of reconfiguration
  - **Develop a robust HLA framework**
    - » ground up design for large scale simulation
    - » address key design issues (repeatability, time management)
    - » simulation initialization
    - » simulation configuration

ATMSDI CTO-07

ACES Build 1 System

- **Provide the modeling toolbox foundation**
  - Emulate the current NAS operational environment
  - Support NAS-wide, gate-to-gate simulation
  - Ability to model entire day-in-the-NAS scenario
  - Emphasis on modeling Traffic Flow Management interactions
    (including Command Center, ATC, and airlines)
  - En Route ATC (CD&R, speed / vector advisories)
  - Simple terminal and airport models (generic vs specific)
  - Varying degrees of AC model fidelity

ACES Build 1 System

- **Assessment capabilities**
  - Measure delay (gate, taxi, airborne)
  - Fuel costs
  - Controller workload (# of vectors, speed changes, # TFM restrictions, CD&R activity)
  - TFM activity
- **Validate with real world data**

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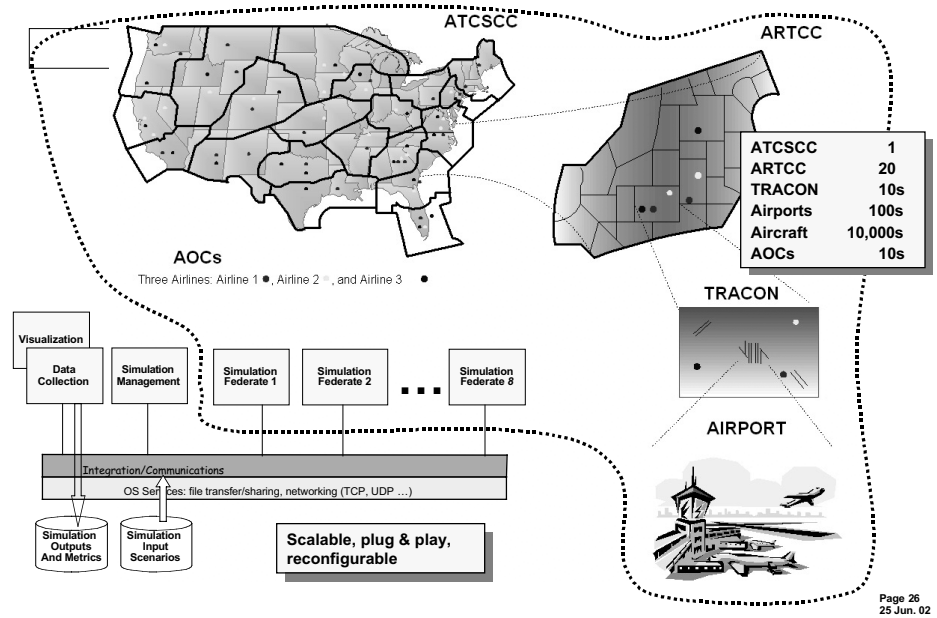
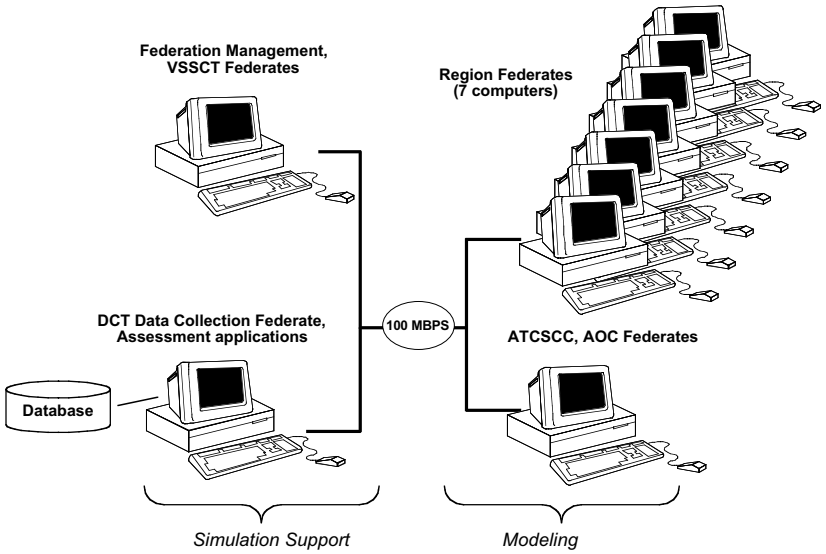
ACES Build 1 System



ACES Build 1 Hardware Configuration



All computers shown are high-end Windows 2000 workstations

Example Assessment Scenarios ACES Build 1 System Could Support

For the current NAS operational environment:

- **SCENARIO #1: Assess NAS-wide effects of increasing en-route sector capacities by 25% for a given traffic scenario and a given set of TFM disturbances**
- **SCENARIO #2: Assess NAS-wide effects of increasing selected airport capacities for a given traffic scenario and a given set of TFM disturbances**
- **SCENARIO #3: Assess NAS-wide effects of reduced separation standards for a given traffic scenario and a given set of TFM disturbances**
- **SCENARIO #4: Assess NAS-wide effects of pre and post 911 traffic mix to a given set of TFM disturbances**
- **SCENARIO #5: Assess NAS-wide effects of planned airport expansions under given set of TFM disturbances and a given traffic demand (current, 2010, 2020?)**

Summary

- **ACES integrated architectural and agent-based modeling approach provide:**
  - a flexible, distributed simulation environment
  - a multi-fidelity “modeling toolkit” to support tailored simulations
  - a simulation environment designed for change
- **Prototype system**
  - small scale proof-of-concept version of ACES
  - demonstrated key features of ACES approach
- **Build 1 system**
  - significant increase in scope over proof-of-concept system
  - in development

NASA AMES
Virtual Airspace Modeling and Simulation (VAMS)

Air Traffic Management System Development & Integration (ATMSDI)

VAMS TIM #2

Airspace Concepts Evaluation System: Build 1 Modeling

George Hunter

28 August 2002

Outline

- Overview of ACES Build 1 models
- Model descriptions
  - Requirements
  - Build 1 approach

Modeling Functionality Overview

- Flight
  - Trajectory propagation
  - Pilot model
- ATCSCC
  - Congestion alert
  - Ground delay program
  - Ground stop program
- ARTCC TFM
  - Impose TFM restrictions
    - » Intra Center
    - » Inter Center
    - » TRACON

Modeling Functionality Overview (cont.)

- ARTCC ATC
  - Meet TFM restrictions
  - Maintain separation (CD&R)
- TRACON TFM
  - Impose TFM restrictions
    - » Airport
    - » Center
  - Receive TFM restrictions
- TRACON ATC
  - Set TRACON delay

Modeling Functionality Overview (cont.)

- Airport TFM
  - Impose TFM restrictions
    - » TRACON
- Airport ATC
  - Runway queing
- Weather
  - Four dimensional winds
  - Convective weather

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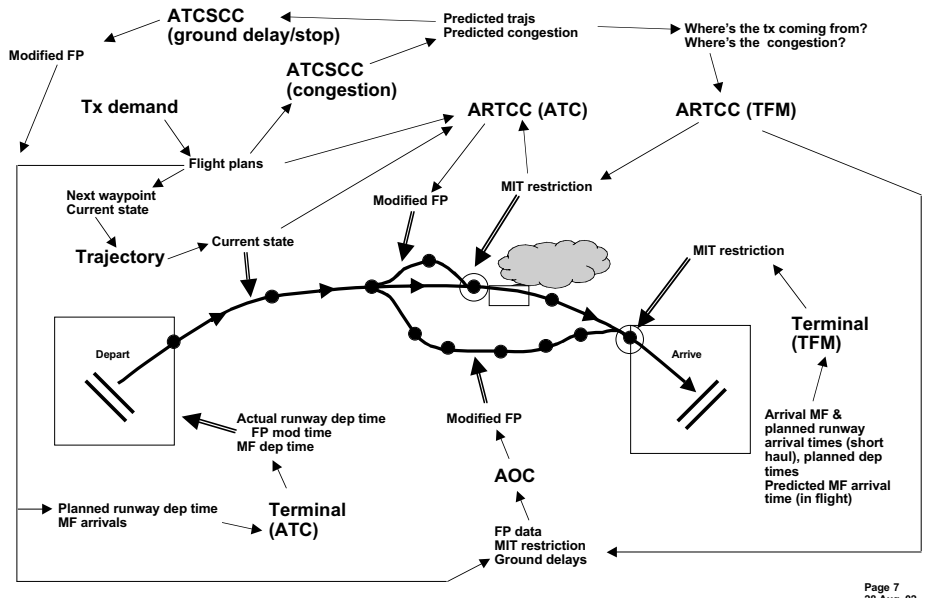
Modeling Functionality Overview (cont.)

- AOC traffic demand
  - Generate a day of traffic
- AOC flight control
  - Cancellations
  - Delays

Overview of Model Interactions



Model descriptions

Trajectory Propagation Requirements

The flight agent shall:

- model the enroute aircraft trajectory including position, velocity and fuel burn.
- incorporate the effects of winds in calculating the aircraft trajectory in the enroute environment.
- model the terminal area aircraft trajectory including flight time and fuel burn.
- model nominal flight times for transitioning terminal airspace unless modified by the TRACON ATC agent to ensure separation of aircraft.

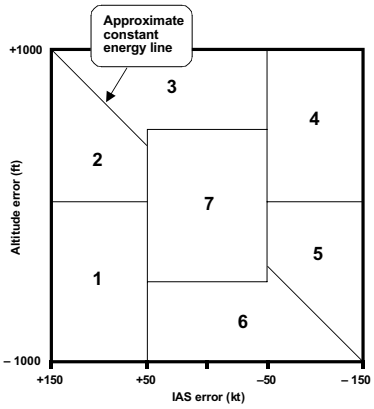
Trajectory Propagation Requirements

The flight agent shall:

- utilize a nominal airport departure taxi time unless additional delays are assigned by the airport due to airport congestion (queing delay).
- conform to nominal climb and decent profiles unless directed by Air Traffic Control.
- model at least 50 aircraft types
- provide the following data for data collection on each flight: airline, flight ID, departure airport, arrival airport, aircraft type ID, actual gate departure time, actual runway departure time, actual departure meter fix time, actual arrival meter fix time, actual runway arrival time, actual gate arrival time, fuel burned

Trajectory Propagation: MPAS

- **Trajectory modeling**
  - Model aircraft trajectory including position, velocity and fuel burn
- **MPAS model**
  - Developed for NASA and FAA
  - 4 degree-of-freedom (DOF) model
    - » Three translational DOFs plus aircraft roll angle
  - Elliptical earth model
    - » WGS-84
  - Pilot model for horizontal- and vertical-plane maneuvers



Vertical Plane Control Logic

ATCSCC Requirements

The ATCSCC agent shall:

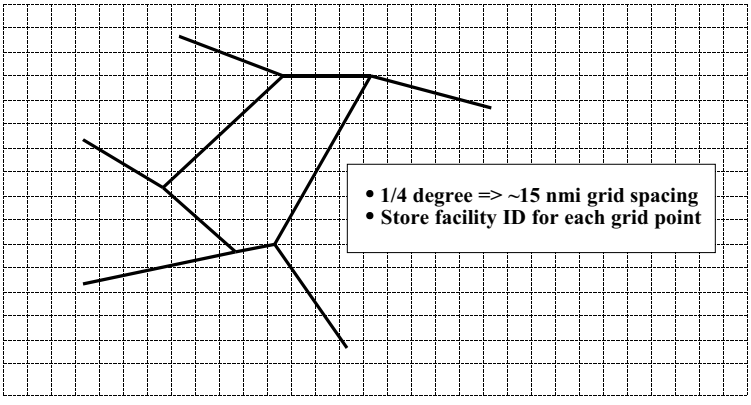
- model the Monitor Alert function.
- model the Ground Stop Program.
- model the Ground Delay Program on a first-come first-serve basis.
- provide the following data for data collection: Monitor Alerts (time issued, time of alert, duration, location); Ground Stop Programs (time issued, start time, duration, facility); and Ground Delay Program (time issued, aircraft IDs, time delays)

ATCSCC Monitor Alert

- Model the Monitor Alert function which predicts and warns of overloaded sectors
- Track/predict sector transit profile for all flights
  - Approximate at one-minute intervals
- Predict maximum instantaneous sector counts in 15 minute intervals
  - Approximate as maximum of fifteen consecutive one-minute sector counts
- Send congestion alert message when predicted sector loading exceeds capacity

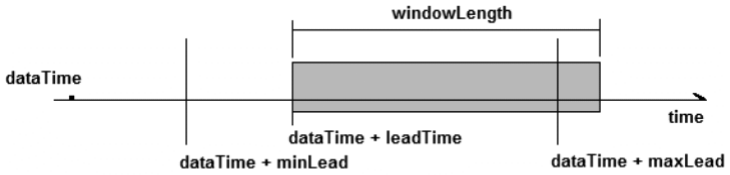
Spatial Lattice

- **Provides table lookup for ARTCC and sector identification**



ATCSCC GDP

- Ground delay program
  - Delay aircraft at point of origin to reduce predicted congestion
- GDP model maintains arrival list with the latest information for each flight scheduled to arrive at each monitored airport
- Use sliding fixed-length time window in GDP decision algorithm

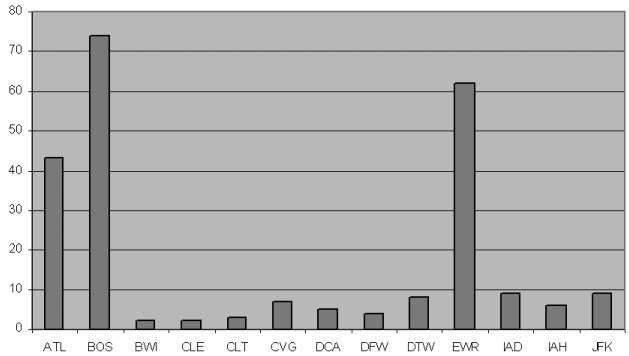


GDP Decision Algorithm Window

ATCSCC GDP

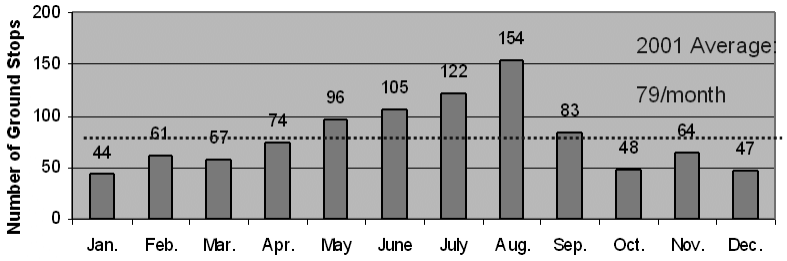
- **Calibrate GDP decision algorithm with historical data**
  - **GDPs have increased in recent years**
  - **GDPs significantly vary with airport**

Year	Number of GDPs	Average per Day*
1998	513	1.4
1999	705	1.9
2000	1083	2.9
2001	799	2.8



ATCSCC Ground Stop

- Ground stop program
  - Similar but simpler than GDP
  - All non exempt arrivals blocked for a time period
    - » Arrival time set to end of time period + 1 minute
  - Convective weather causes more GS activity



ARTCC TFM Requirements

The ARTCC TFM agent shall:

- analyze all predicted congestion events and determine if it can be handled with intra-Center restrictions or if it requires a combination of intra-Center and inter-Center restrictions.
- analyze imposed adjacent ARTCC TFM restrictions and TRACON imposed TFM restrictions, responding with intra and / or inter-Center restrictions
- provide the following data for data collection: Traffic flow restrictions (time issued, time in effect, restriction)

ARTCC TFM

- **Traffic flow restrictions**
  - Model the derivation of traffic flow restrictions to alleviate congestion, including both intra- and inter-Center restrictions
- **Receive congestion alert**
- **Decide whether to take action or not**
  - Consider severity of congestion and effectiveness of flow restriction
- **Decide whether to delay aircraft within facility or to impose restrictions upstream**
- **Model MIT with requested delays**
  - Relatively easy to identify flights to be delayed and desired delay
  - More difficult to implement MIT
  - Requested delay is a good approximation of MIT

ARTCC ATC Requirements

The ARTCC ATC agent shall:

- predict conflicts between aircraft in the en route airspace providing adequate time (TBD) to resolve the conflict
- issue speed or vector advisories to aircraft to comply with conflict resolution and / or TFM constraints.
- deliver aircraft conflict free to adjacent facilities (ARTCC or TRACON)
- provide the following data for data collection: ATC TFM restriction (time issued, time of restriction, AC IDs, action taken); ATC separation action (time issued, time of ATC action, AC IDs, action taken)

ARTCC ATC

- **Meet restrictions and maintain separation**
  - Model the air traffic control of aircraft to adhere to traffic flow restrictions and maintain aircraft separation
- **Delay strategies**
  - Speed control
    - » Use speed reduction if sufficient
  - Path control
    - » Use path stretching when necessary
      - S-turn

- **Maintain separation**
  - Check for loss of separation
  - Use CD&R algorithms to resolve predicted separation loss
    - » ~15 minute prediction horizon
    - » FACET CD&R algorithm a likely candidate

TRACON TFM and ATC Requirements

The TRACON TFM Agent shall:

- utilize a delay distribution function to determine the degree of TRACON delay absorption for delayed arrival aircraft.
- determine arrival and departure flight times through its airspace
- assign scheduled landing times consistent with airport arrival rates.

- Each TRACON shall be represented as a generic TRACON with 4 independent arrival and 4 independent departure meter fixes
- Scheduled TRACON flight times will be nominal flight times dependent on aircraft type.

TRACON TFM and ATC

- **TFM**
  - Manage TRACON-ARTCC boundary crossing traffic flow restrictions at Arrival and Departure Fixes
    - » Receive TFM restrictions (delay per flight) from Airport and ARTCC TFM agents
    - » Pass airport capacity-based restrictions to ARTCC TFM
    - » Pass en route congestion-based restrictions to Airport TFM
- **ATC**
  - Process flights through the TRACON airspace
    - » Access actual takeoff arrival and actual fix crossing times
    - » Compute TRACON flight time for departures and arrivals
    - » Apply minimum separation requirement at Departure Fix
    - » Update/pass scheduled landing times
    - » Update/pass scheduled departure fix crossing times

Airport TFM Requirements

The Airport TFM agent shall:

- send TFM restriction messages to the Airport ATC agent describing delay constraints on scheduled departure flights
- determine the time-varying airport departure and arrival acceptance rates, accounting for meteorological conditions and capacity constraints.
- impose TFM restrictions for arrival flights within the TRACON and to adjacent ARTCCs in response to limited capacity at the airport.
- impose TFM restrictions for departure flights at the airport in response to limited capacity in the adjacent ARTCC.

Airport TFM

- **Assign airport runway arrival and departure acceptance rates based on:**
  - Airport arrival and departure maximum acceptance rates
  - Arrival versus departure loading per flight schedule
  - Current airport queue updates received from Airport ATC agent
- **Determine runway arrival and departure TFM restrictions (delay per flight) to satisfy arrival and departure acceptance rates**
- **Pass arrival and departure acceptance rates to**
  - Airport ATC agent
  - ATCSCC agent
- **Pass Airport-based TFM restrictions to TRACON TFM Agent**
- **Update/Pass scheduled takeoff times in flight data set**
  - ATCSCC ground delay and ground stop delay assignments
  - Departure constraints relayed from to TRACON TFM

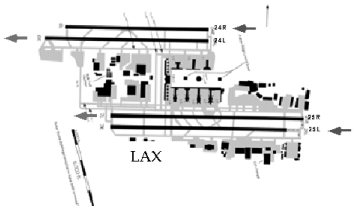
Airport ATC Requirements

The Airport ATC agent shall:

- revise the departure schedule to accommodate TFM restrictions.
- revise the departure schedule to reflect AOC flight delays and cancellations.
- determine takeoff and landing spacing requirements
- assign actual times of runway departure and arrival time corresponding to the spacing requirements.
- assign actual gate departure times and actual gate arrival times
- maintain data describing runway actual departure and arrival queuing
- Each airport shall be represented by independent arrival and departure traffic flows and arrival and departure capacities

Airport ATC

- **Determine actual runway departure and arrival times**
  - Treat airport as having aggregate departure and arrival capacities
  - Queuing model assigns actual landing and takeoff times
- **Update/Pass actual takeoff and landing time in flight data set**
- **Pass current airport queue updates to Airport TFM agent**



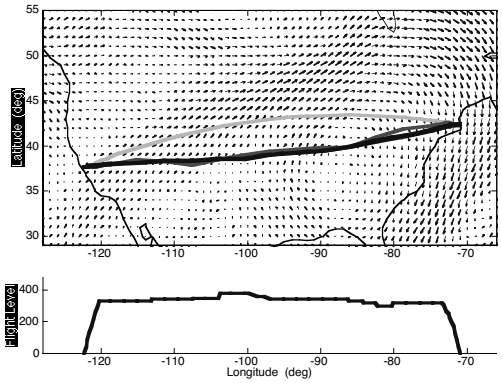
Weather Requirements

The Weather model shall:

- utilize historical wind data sets (e.g. RUC data) to represent truth winds
- interpolate between wind data sets to provide a 4D wind vector
- model inclement weather as capacity reductions of en route airspace or airports

Weather

- **Wind**
  - Use gridded, time-varying data
    - » RUC from January 29, 2002
    - » Use 4D interpolation
- **Heavy weather**
  - Model as temporary capacity reduction
    - » Sectors and airports
  - Will cause traffic delay



AOC/Flight Control Requirements

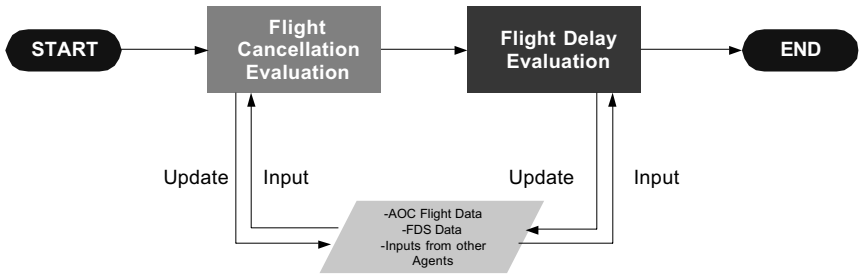
The AOC agent:

- shall cancel flights in high frequency markets when gate departure times exceed a preset time limit.
- shall impose airline induced flight delays to preserve flight connections within preset time limits
- can exhibit different behavior through adjustment of cancelation and delay time limits.

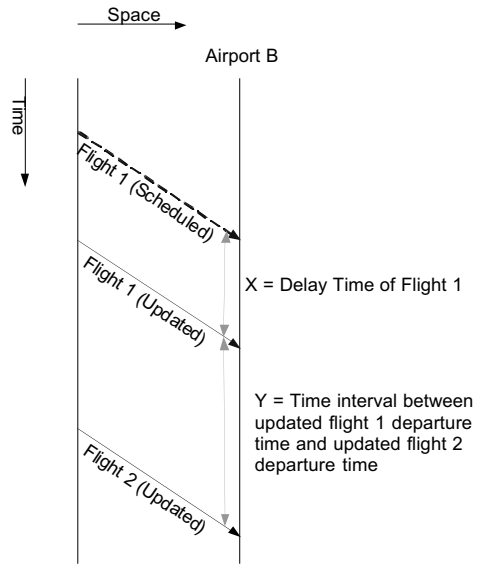
AOC/Flight Control

- AOC real-time flight control
  - Model the airline control of flights
    - » Cancellations
      - Primarily due to extended ATC takeoff delay
    - » Delays
      - E.g., for delayed connecting flights

AOC Real-Time Flight Control Process



Cancellation Algorithm



Cancellation Algorithm

IF

1) X > a pre-set tolerable flight delay time

and

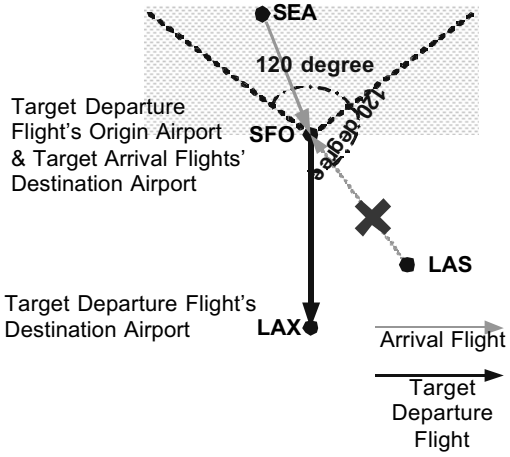
2) Y < a pre-set flight time interval between flight 1 and flight 2

THEN

Cancel Flight 1

Delay Algorithm

Need to Identify the amount of time the Target Departure Flight has to be delayed



IF
the arrival flight's departure airport fall within the shade area

THEN
we identify that the arrival flight as a connecting arrival, which has a passenger connection relationship with the target departure flight

The amount of delay for the target departure flight is the max delay of all connecting arrivals.

e.g. SEA – SFO is a valid connecting arrival for SFO – LAX flight.
LAS – SFO is not a valid connecting arrival for SFO – LAX flight.

AOC/Traffic Demand Requirements

The traffic demand model shall:

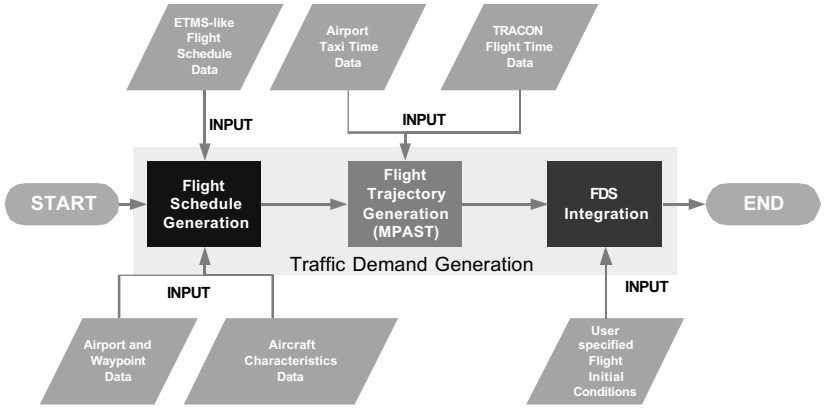
- create a realistic set of scheduled flights using historical data files to represent the current NAS operational environment
- specify a gate-to-gate flight plan
- utilize generic meter fixes for TRACON entry and exit points
- provide the following data: airline, flight ID, departure airport, arrival airport, aircraft type ID, scheduled gate departure time, scheduled runway departure time, scheduled departure meter fix time, scheduled arrival meter fix time, scheduled runway arrival time, scheduled gate arrival time

AOC/Traffic Demand

- Traffic demand model
  - Model traffic demand for a 24 hour period
    - » Each flight described
      - City pair, aircraft type, flight plan, departure time, connection information, etc.
  - Based on historical data
    - » Therefore have realistic traffic patterns and terminal-area loading
  - ~200 biggest airports
  - ~20,000+ flights

Traffic Demand Generation Processes

ATMSDI CTO-07



NASA AMES
Virtual Airspace Modeling and Simulation (VAMS)

Air Traffic Management System Development & Integration (ATMSDI)

VAMS TIM #2

Airspace Concepts Evaluation System: Data Flow

Douglas Sweet

28 August 2002

Outline

- **Build 1 Inputs**
  - User defined
  - NAS Simulation data
  - Internal simulation data
- **Build 1 Outputs**
  - Validation outputs
  - Additional outputs

ACES Build 1 Inputs

- **User defined input data**
  - **Airspace**
    - » NAS-wide
    - » Selected subset of current NAS
    - » Airports
  - **Scheduled Flight Demand**
    (ETMS-like scheduled flight plans)
    - » for each flight (airline ID, flight ID, departure airport, arrival airport, aircraft type, scheduled gate departure time, schedule gate arrival time, flight path (waypoints, cruise altitudes, speeds)
  - **Initial airport meteorological conditions** (IMC vs VMC)
  - **Winds** (historical RUC files, hourly updates)
  - **AOC cancellation and delay time limits**

ACES Build 1 Inputs

- **User defined input data (con't)**
  - **Run-time airport capacity changes**
    (Airport ID, time, duration, change):
    - » Change due to weather
    - » Change due to reduction in available runways
    - » Changes in meteorological condition (IMC vs VMC)
    - » Changes due to introduction of new concept
  - **Run-time en route sector capacity changes**
    (Sector ID, time, duration, change)
    - » Change due to weather
    - » Change due to introduction of new concept

ACES Build 1 Inputs

- **NAS data sets needed by the simulation***
  - **Airspace Definitions**
    - » ARTCC / ARTCC sectors and boundaries
    - » Airports and locations
    - » Waypoints
  - **Capacities**
    - » Airport capacities (arrival, departure, total) for both IFR and VFR conditions
    - » En route sector capacities
  - **Aircraft Data**
    - » Represent 50 aircraft types / performance

** default to existing NAS specifications*

ATMSDI CTO-07

ACES Build 1 Inputs

- **Internal Simulation Data sets***
  - ARTCC / ARTCC sectors to grid mapping
  - Model to data set mapping
  - Agent to Federate mapping
  - Federate to computer mapping
  - Flight Data Set for each flight (output of Flight Demand model)

** used for ACES configuration and initialization*

ACES Build 1 Validation Outputs

- **Flights**
  - Scheduled and actual gate departure time
  - Scheduled and actual runway departure time
  - Scheduled and actual flight time
  - Scheduled and actual runway arrival time
  - Scheduled and actual gate arrival time
  - fuel utilized
  - Airline
  - Airline flight number
  - Internal simulation flight number (unique)
  - Departure Airport
  - Arrival Airport
  - Cancelled flight (Y/N)

ATMSDI CTO-07

ACES Build 1 Validation Outputs

- **ARTCC ATC (by Sector)**
  - Speed advisories issued in specified time period (15 min.)
  - Vector advisories issued in specified time period (15 min.)
  - TFM advisories in a specified time period (15 min.)
  - CD&R advisories in a specified time period (15 min.)

Other ACES Build 1 Outputs . . .

- **TFM activities**
  - **Airport TFM advisories**
    - » Time issued, duration, action taken
  - **TRACON TFM advisories**
    - » Time issued, duration, action taken
  - **ARTCC TFM advisories**
    - » Time issued, duration, action taken
  - **ATCSCC TFM advisories**
    - » Time issued, duration, action taken
  - **AOC cancellations and delays**
    - » Time issued, AC info, delay duration

Other ACES Build 1 Outputs . . .

- **Other possibilities:**
  - **En route CD&R activity**
    - » predicted separation before resolution
    - » actual separation after resolution
  - **TRACON flight delays**
    - » scheduled flight times
    - » actual flight times
  - **ARTCC flight delays**
    - » scheduled flight times
    - » actual flight times
  - **En Route Sector Loading**
    - » scheduled sector counts (15 minutes)
    - » actual sector counts (15 minutes)

NASA AMES
Virtual Airspace Modeling and Simulation (VAMS)

Air Traffic Management System Development & Integration (ATMSDI)

VAMS TIM #2

Airspace Concepts Evaluation System: Build 1 Assessment and Validation

Dr. Paul Abramson

28 August 2002

ATMSDI CTO-07

Build 1 Assessment Objectives

- **Demonstrate the ability to perform assessment of NAS performance under various operating conditions**

Build 1 Validation Objectives

- Obtain the same order of magnitude for the simulated performance metric vs NAS data for given scenarios
- Ensure that the simulation results demonstrate the same trends as real-world NAS data over a range of scenarios

ACES Build 1 Assessment and Validation

The Build 1 assessment and validation involves

- Defining the metrics to be used
- Defining the data to be collected
- Demonstrating the capability to perform assessments
- Validating the simulation

Assessment/Validation Scenarios

	Initial	Stretch Adds
NAS System Characteristics	Current NAS	20% increase in airport acceptance rates
NAS Environmental Factors	No significant en route weather Scripted en route winds Good weather at all airports	Locally bad weather at selected airports
NAS Demand	Low traffic day High traffic day	High Traffic + 20%

Build 1 Metrics

- **Flight Event Times**
- **Delays**
- **Total Fuel Consumed**
- **Controller Workload**
- **TFM Restrictions**

Flight Events and Delays

- **Gate Departure**
- **Taxi Out**
- **Take Off**
- **Airborne**
- **Landing**
- **Taxi In**
- **Gate Arrival**
- **Block Time**

Note: Not all events and delays an be validated against real data. This depends upon the availability of real data

Flight Events Eye Chart

	TIMES				DELAYS				AVERAGE DELAYS			
Flight Event	Actual	Measured (ETMS/OOOI)	Phase II Simulation	Can We Validate?	Actual	Measured (ETMS/OOOI)	Phase II Simulation	Can We Validate?	Actual	Average from ASPM	Ave from Phase II Simulation	Can We Validate?
1. Gate Departure	True Gate Departure	Not available OOOI Out	Set to GDT from OAG + Simulated Gate Departure Delay	No Yes	True Gate Departure Time - Scheduled Gate Departure Time	Not available OOOI Out - GDT from OAG	Simulated Gate Departure Time - Scheduled Gate Departure Time	No Yes	Ave of True Gate Departure Delays	Ave OAG Based Gate Delay	Ave of Simulated Gate Departure Delay	Yes
Scheduled Gate Departure	GDT from OAG	GDT from OAG	GDT from OAG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. Taxi-Out	True Taxi-Out	Not available OOOI Off - OOOI Out	Set to Nominal Value + Simulated Taxi Out Delay	No Yes	True Taxi Out Delay	Not available	Simulated Taxi Out Delay	No	Ave of True Taxi Out Delay	Ave Taxi Out Delay	Ave of Simulated Taxi Out Delay	Yes
3. Take-Off	True Take-Off	DZ - Average Departure Gap OOOI Off	Simulated Gate Departure Time + Simulated Taxi Out Time	Yes Yes	True Gate Departure Delay + True Taxi Out Delay	Not available	Simulated Gate Departure Delay + Simulated Taxi Out Delay	No	Ave of True Take Off Delay	Ave OAG Based Airport Departure Delay	Ave of Simulated Take Off Delay	Yes
4. Airborne	True Airborne	Measured Landing Time - Measured Take Off Time OOOI On - OOOI Off	Calculated in Simulation	Yes Yes	True Airborne Time - Scheduled Airborne Time	Measured Airborne Time - ETE from FZ msg	Simulated Airborne Time - ETE from FZ mag (see note below)	Yes Yes	Ave of True Airborne Delay	Ave Airborne Delay	Average Simulated Airborne Delay	Yes
5. Landing	True Landing	AZ - Average Arrival Gap OOOI On	Set to Simulated Take Off Time + Simulated Airborne Time	Yes Yes	True Gate Departure Delay + True Taxi Out Delay + True Airborne Delay	Not available	Simulated Gate Departure Delay + Simulated Taxi Out Delay + Simulated Airborne Delay	No	Ave of True Landing Delay	Ave Gate Departure Delay + Average Taxi Out Delay + Ave Airborne Delay	Ave of Simulated Landing Delay	Yes
6. Taxi-In	True Taxi-In	Not available OOOI In - OOOI On	Set to Nominal Value	No Yes	True Taxi In Delay	Not available	Not calculated, set to 0	No	Ave of True Taxi In Delay	Ave Taxi In Delay	Not calculated, set to 0	No
7. Gate Arrival	True Gate Arrival	Not available OOOI In	Set to Simulated Landing Time + Simulated Taxi In Time	No Yes	True Landing Delay + True Taxi In Delay	Not Available OOOI In - GAT from OAG	Set to Simulated Landing Delay	No Yes	Ave of True Gate Arrival Delay	Ave OAG Based Airport Arrival Delay	Ave of Simulated Gate Arrival Delay	Yes
Scheduled Gate Arrival	GAT from OAG	GAT from OAG	GAT from OAG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8. Block Time	True Gate Arrival Time - True Gate Departure Time	Not available OOOI In - OOOI Out	Set to Simulated Gate Arrival Time - Simulated Gate Departure Time	No Yes	True Gate Arrival Delay - True Gate Departure Delay	Not available Measured Gate Arrival Delay - Measured Gate Departure Delay	Set to Simulated Gate Arrival Delay - Simulated Gate Departure Delay	No Yes	Ave of True Block Time Delay	Ave Block Time Delay	Ave of Simulated Block Time Delay	Yes

The difference between the measured airborne delay and the Phase II simulation airborne delay is mathematically equal to the difference between the measured airborne time and the Phase II simulation airborne time. Therefore the conclusions about validation of airborne delay are the same as those for validating the airborne times. However, when validating simulated airborne delays against the average delays obtained from ASPM data, the simulated airborne delay must be calculated using the formula as above.

Observations from Flight Event Chart

- Many real world data can only be partially or imprecisely observed
  - Gate Departure, Gate Arrival, Taxi Out, Taxi In times require OOOI data, available on only 10 airlines at selected airports
  - Airborne Time requires OOOI for accurate measurement; can only be imprecisely obtained from ETMS data
  - Many delay measures are not known because "nominal" values are not know (against which to measure delays)
    - » Taxi In/Out/Take Off/Landing delay
- The previous eye chart identifies parameters that can be accurately validated, approximately validated, and not validated at all

Total Fuel Consumed

- Fuel consumed by all aircraft in a scenario
- Cannot be validated (lack of real world data)

Controller Workload Metrics

- Number of speed changes per 15 minute interval
- Number of path changes per 15 minute interval
- Number of speed changes per 15 minute interval due to CD&R action by en route agent
- Number of path changes per 15 minute interval due to CD&R action by en route agent
- Cannot be validated (lack of real world data)

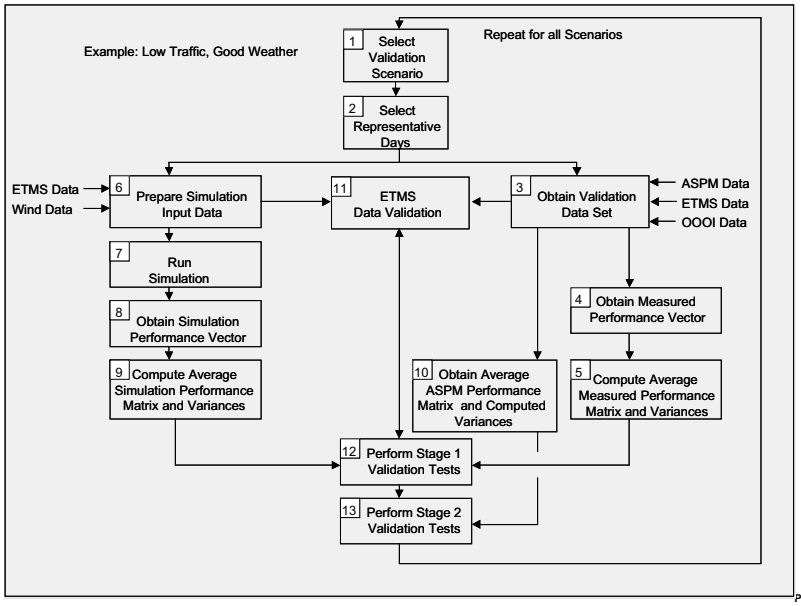
TFM Restrictions

- ATCSCC
- ARTCC
- TRACON
- Airport
- AOC

Limited Build 1 Assessments

- **Build 1 assessments = validation scenarios because**
  - **No new DSTs to "assess"**
  - **Limited time available for assessments**

Validation Process



Steps in the Validation Process

- Boxes 1 – 2 Pick the days to be simulated and validated
- Box 3, 4, 5, and 10: Obtain and process the real world data against which we will validate
- Box 6: Prepare simulation input data (mainly flight plans and winds aloft data
- Boxes 11: ETMS data validation to ensure that ETMS flight plan data used to drive the simulation compares (on average) with average ETMS derived data from FAA ASPM data system
- Boxes 7, 8, and 9: Run the simulation and process the output data
- Box 12: Stage 1 Validation – Average simulation outputs compared to averages of pertinent input data (OOOI, ETMS data)
- Box 13: Stage 2 Validation – Average simulation outputs compared to ASPM average performance data (much richer set of averages available in ASPM)

Run multiple days per scenarios, and then multiple scenarios

Sources of Validating Data

- FAA ASPM Data System – average performance at 50 airports every 15 minutes
- FAA ASPQ Data System – OOOI data
- ETMS Data – Flight plan plus Activation Times (~ takeoff), Deactivation Times (~ landing), Estimated Time En Route

Real World Issues

- Need accurate winds aloft data for each day to be validated
  - Nobody seems to have or archive hourly winds aloft data
  - Rapid Update Cycle data (short term winds aloft forecasts) are going to be used as surrogate for actual winds aloft
- Many parameters are hard to observe
  - OOOI data is essential for some elements, but only exists for 10 airlines at some airports
  - Actual departure and arrival times from ETMS are only approximate
- Build 1 simulation has modeling limitations that must be accounted for in the validation effort
  - Limited Surface Model
  - Low Fidelity Terminal Area models
  - Effects of Bad Weather via flow restrictions

Questions?

Systems Evaluation and Assessment (SEA) Sub-Element

Real-Time Simulation Validation

Sandy Lozito
Level 3 Manager
SEA Sub-element

System Evaluation and Assessment General Tasks

- **Develop scenarios and metrics for evaluation of the SLIC concepts**
- **Conduct an initial validation assessment of the VAST real-time tools**
- **Conduct an initial assessment of the selected concepts**
- **Conduct an initial assessment of the integrated concepts**
- **Conduct the final evaluation of the integrated concept(s) using the VAST tools**

Real-time Simulation Validation Overview

- **Purpose: To test real-time toolbox in FY04 (Not to test a VAMS concept!)**
- **System Evaluation and Assessment (SEA) is responsible for experimental requirements**
  - **Approach**
    - **Select a concept that has been tested in previous work (field or simulation or other)**
    - **Configure the real-time tools to test this concept using the current set of tools**
    - **Attempt to replicate the findings from previous work using the real-time toolbox to validate the toolbox development**
    - **Provide pathways to future tests in the real-time environment**

Real-Time Simulation Validation Issues

- **A topic for the validation study must be relevant to general VAMS themes**
  - **The topic should offer an opportunity to test more than one airspace domain (e.g., TRACON + En route) for human-in-the loop considerations**
  - **The topic should test other models and tools along with the human-in-the loop considerations**
  - **The topic should be in-line with topics expected from VAMS concepts**
- **The requirements should not redirect the development efforts that will be ongoing for the real-time toolbox**
- **The experimental requirements should help prioritize the development of the toolbox**

Real-Time Simulation Validation
Parameters and general approach

- **Include at least two facilities**
- **Test at least two parts of the triad**
- **Emphasize common architecture and data management and analysis**
- **Sequential testing prior to FY04 test**
- **Should be concerned with automation topics, with an emphasis upon human factors**
- **Development of real-time simulation environment should be closely related to some of the development requirements for the advanced concepts derived from the SLIC subelement**

Real-Time Simulation Validation
Thoughts about our approach

- **To validate, we're looking for results that are consistent with "baseline" data**
  - **Extensive fast-time study**
  - **Real-time simulation**
  - **Field site evaluation**
  - **Common findings across studies**
- **Human factors issues testing by specific event**
  - **Failure**
  - **Blunder**
  - **Coordination requirement**

Real-time Simulation Validation
General Plan: Arrival sequence with surface operations

- **Nominal operations will be comparable to previous data (capability validation)**
- **Abnormal events will demonstrate how the capability can be used to examine human factors issues related to the development of distributed, automated systems**
- **Simulation operations using expanded VLab facility will demonstrate how experimenter can conduct an evaluation from one central location**
- **Simulation will collect parameters of operation which are useful for upgrading models and for fast-time operations**

Real-time Simulation Validation
Operations

- **Multiple arrival streams at operational capacity into terminal area (possibly DFW)**
  - **Minimum spacing between aircraft**
  - **Normal but busy for pilots and controllers**
- **Self-spacing operations**
  - **Controller has overall responsibility for TRACON arrival operations**
  - **Controller can clear suitably equipped aircraft for self-spacing**
- **Aircraft landing and taxiing**
- **Other surface traffic represented**

Real-time Simulation Validation
Creation of abnormal event

- After some time of normal but busy operations, simulate a problem on the surface that constrains the traffic movement (possibly a disabled vehicle on a taxiway, runway incursion).
  - This should constrain the arrival flow as well as the surface movement, thereby creating more challenges
- Fail one or more of the automation tools or represent corrupted data
  - This should create challenges throughout the system if we create a failure on a critical system
- Blunder (e.g., aircraft turns onto runway)
  - This may constrain most of the traffic in the airport area

Real-time Simulation Validation
Automation tools that might apply

- FAST tools for the controller
- Cockpit display of traffic for the pilots
- Self-spacing algorithms
- SMS for controller surface tool
- T-NASA for pilot surface tool

Real-time Simulation Validation Facilities

- **CVSRF simulator (Advanced Concept Flight Simulator)**
- **Airspace Operations Laboratory (AOL)**
- **Future Flight Central (hopefully it has SMS integrated)**
- **Facility outside Ames (controller simulator at NTX)**
- **Ability to use Vlab-type capabilities**

Real-time Simulation Validation Data collection requirements

- **Emphasis will be on validating the test environment**
  - **Objective data**
    - **Discrete data**
    - **Continuous data**
    - **Time synchronization data**
  - **Subjective data**
    - **Video/audio capabilities**

Real-time Simulation Validation
Participants and Research Team Involvement

Participants

- Commercial pilots
- TRACON controllers
- Tower controllers

Research team involvement

- Research representative of surface operations and automation for controllers
- Research representative of surface operations and automation for pilots
- Research representative of TRACON operations and automation for controllers
- Research representative of TRACON operations and automation for pilots
- SEA research team

Real-time Simulation Validation
Some Remaining Issues

- What will our metrics be for the validation of the real-time simulation environment?
- What are the appropriate scenario events to test the simulation?
- How will we map between the requirements for the real-time simulation environment and the non-real-time simulation environment?
- Is the integration of facilities and exchange of data between them too difficult for this time frame?

VAST RT

Virtual Airspace Simulation Technology Real-Time Simulation Sub-Element (VAST-RT) TIM #2

VAST RT

AGENDA

VAST-RT Overview
- **VAST-RT in VAMS**
- **VAST-RT and ACES**

VAST-RT Concept
- **Issues to be Investigated**
- **System Concept Diagram**
- **System Functionality**

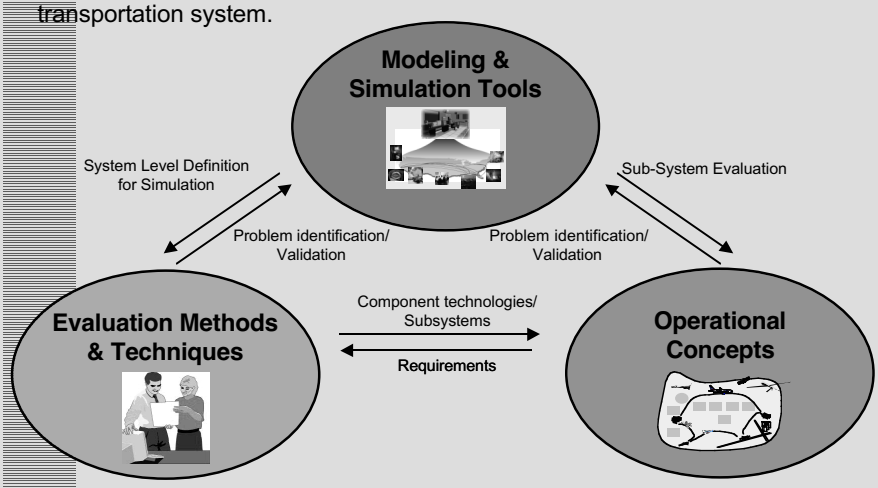
System Components
- **System Architecture**
- **System Integration**
- **Simulation Models**
- **Collaborative Development Environment (CDE)**

Wrap up

VAST RT

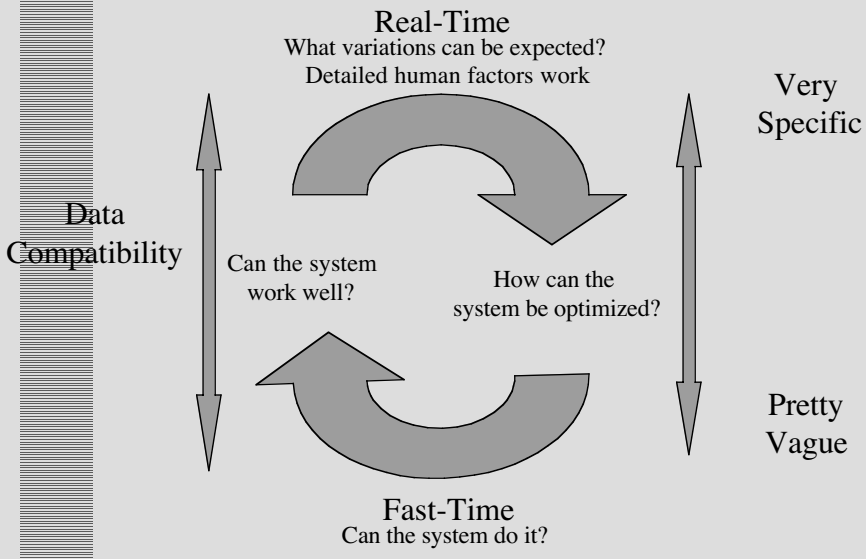
VAST WITHIN VAMS

Develop the capability to simulate operations within the National Airspace System (NAS) to levels of fidelity sufficient for the research being performed. This capability will provide a safe, cost-effective, common, flexible, and accessible platform for evaluating ATM concepts for the future air transportation system.



VAST RT

VAST-RT & ACES



VAST RT

VAST-RT & ACES

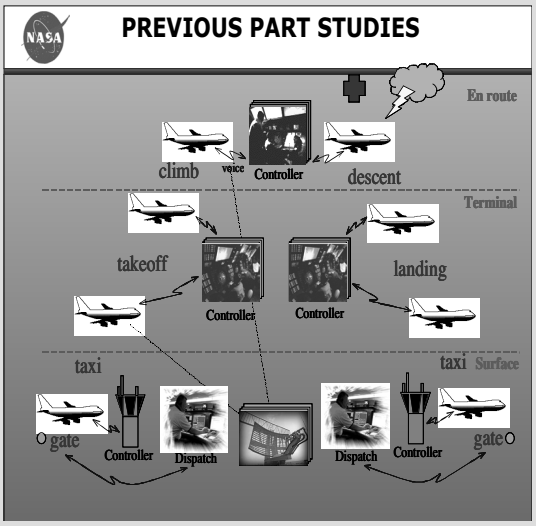
ACES will provide system wide studies of the overall concept. Where it is appropriate, ACES, acting through SEA will provide requirements for detailed VAST-RT studies.

VAST-RT will examine the detailed issue using RT simulation techniques and provide refined data to ACES for their next Non-RT study.

ACES will make additional studies and this process will repeat as often as is required.

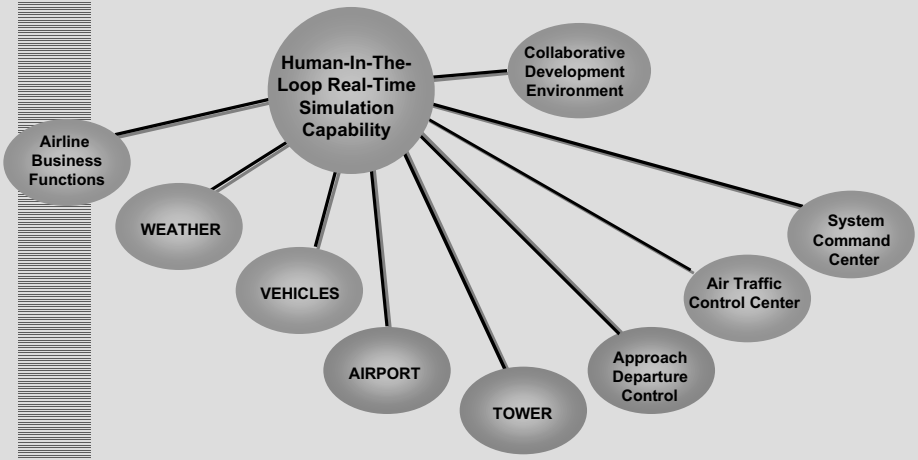
VAST RT

Issues to be Investigated



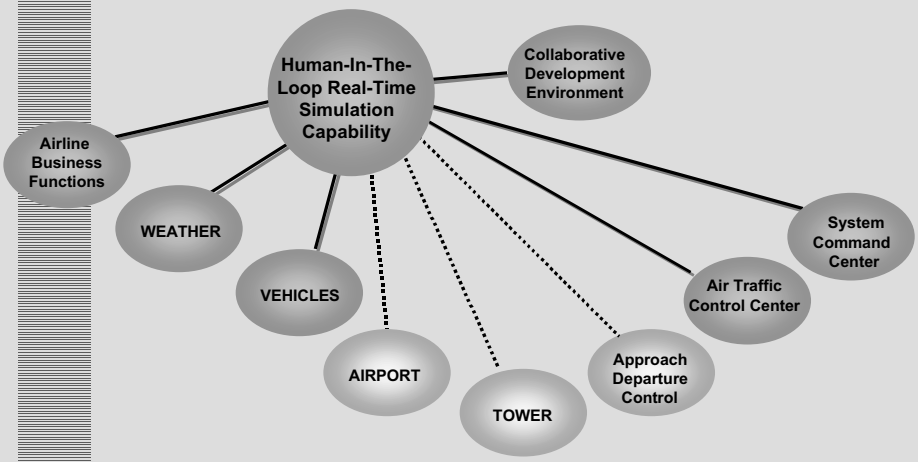
VAST RT

VAST-RT CONCEPT



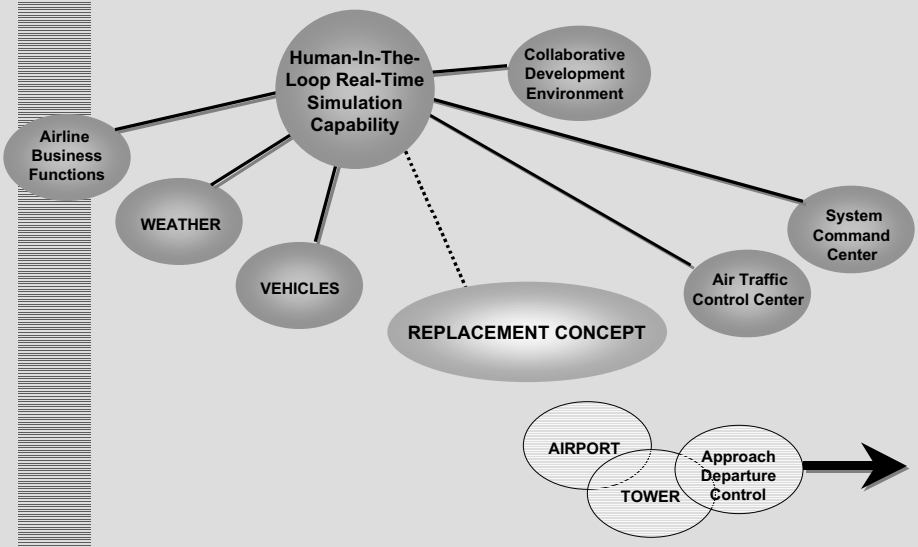
VAST RT

VAST-RT CONCEPT



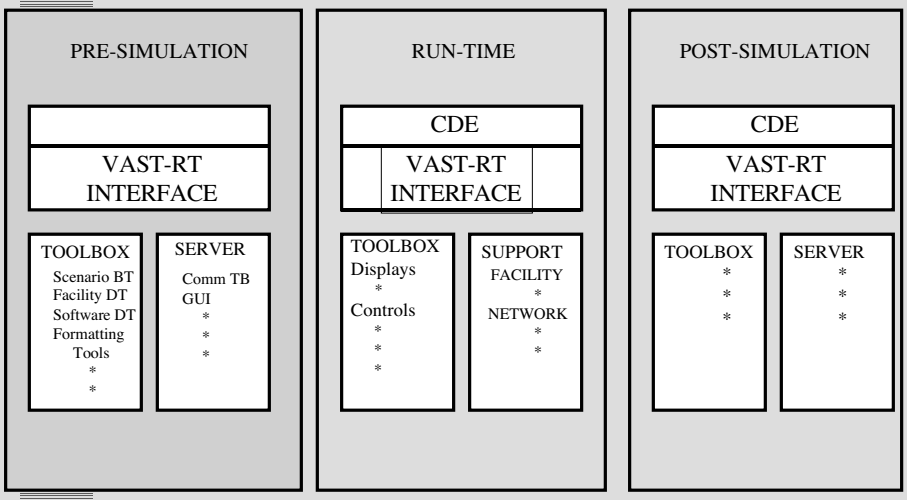
VAST RT

VAST-RT CONCEPT



VAST RT

USING VAST-RT TOOLS



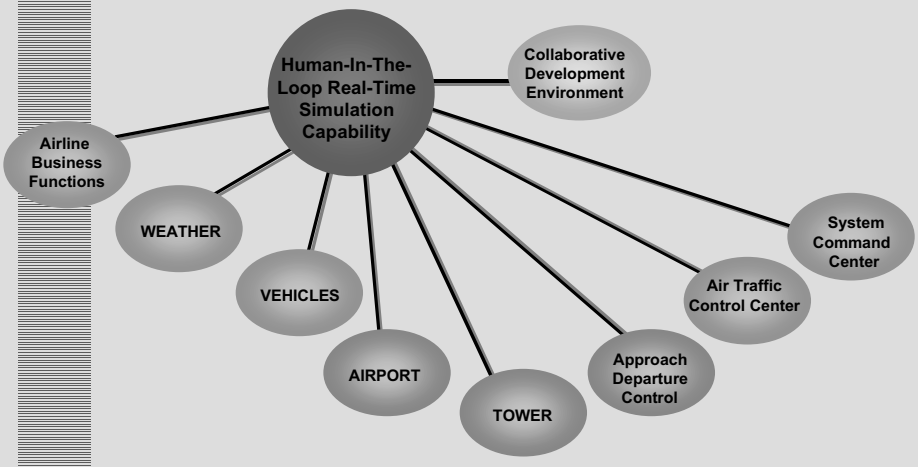
~~Non~~-VAST-RT Tools can be placed in the appropriate toolbox but only if they conform to ~~the~~ VAST-RT Interface Requirements Specification both in their operation and in their output.

VAST RT

VAST Real-Time System Architecture

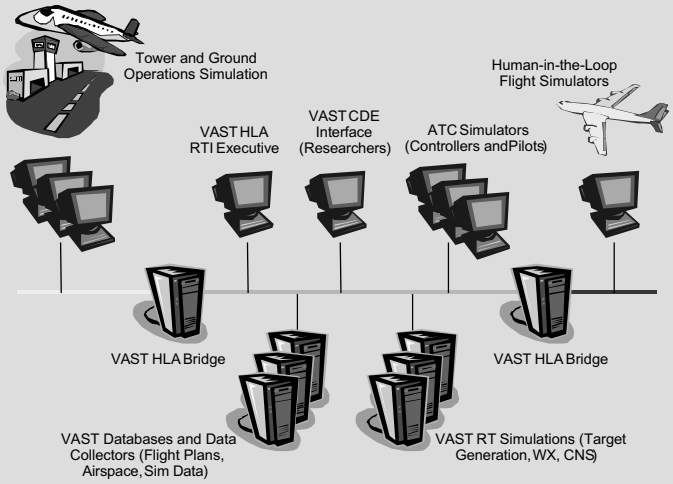
VAST RT

SYSTEM ARCHITECTURE



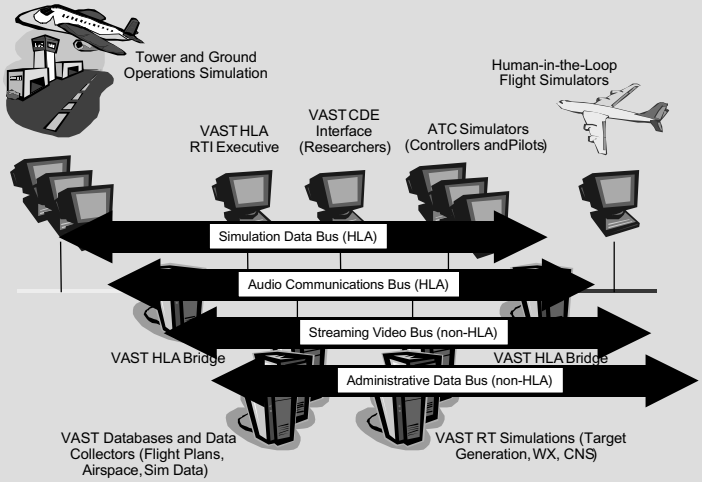
VAST RT System Architecture

Example of a VAST-RT Distributed Simulation



VAST RT VAST-RT Architecture

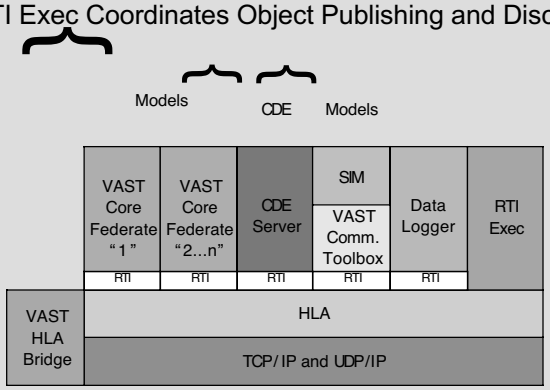
The VAST-RT Architecture provides the data buses to interconnect all of the participants



VAST RT Federation Block Diagram

Federates communicate with each other via HLA RTI's.

RTI Exec Coordinates Object Publishing and Discovery.



VAST RT Translation Toolboxes

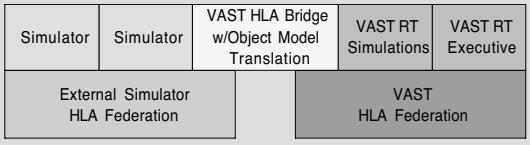
VAST-RT HLA Bridge Advanced Features:

Object Model Translation Toolbox:

Coordinate Transformations, Message Translation

Simulation State Memory:

Improved Performance for Late Joining Systems

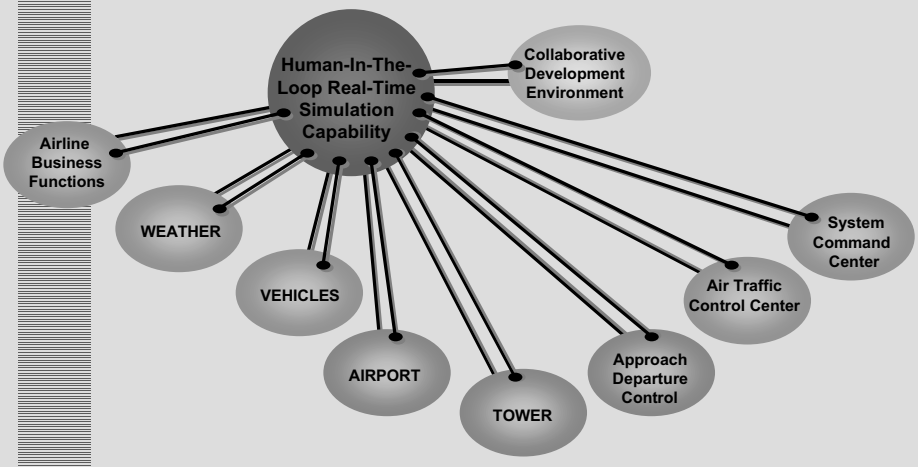


VAST RT

VAST Real-Time System Integration

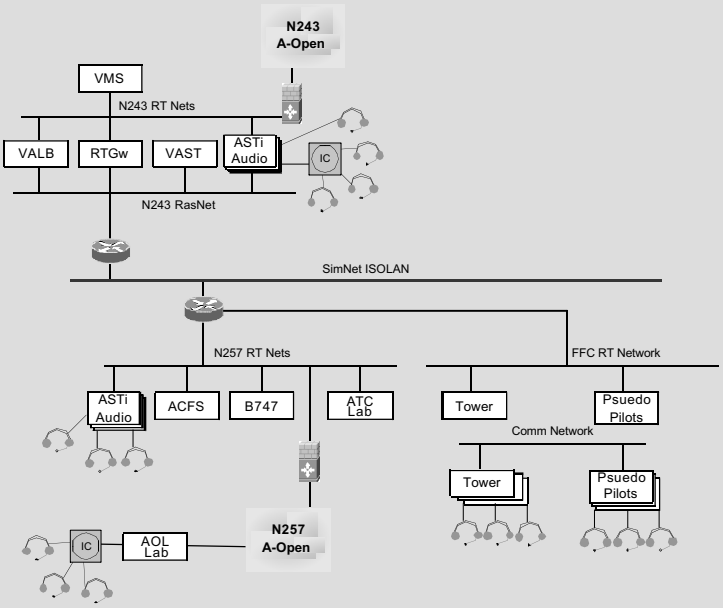
VAST RT

VAST-RT CONCEPT



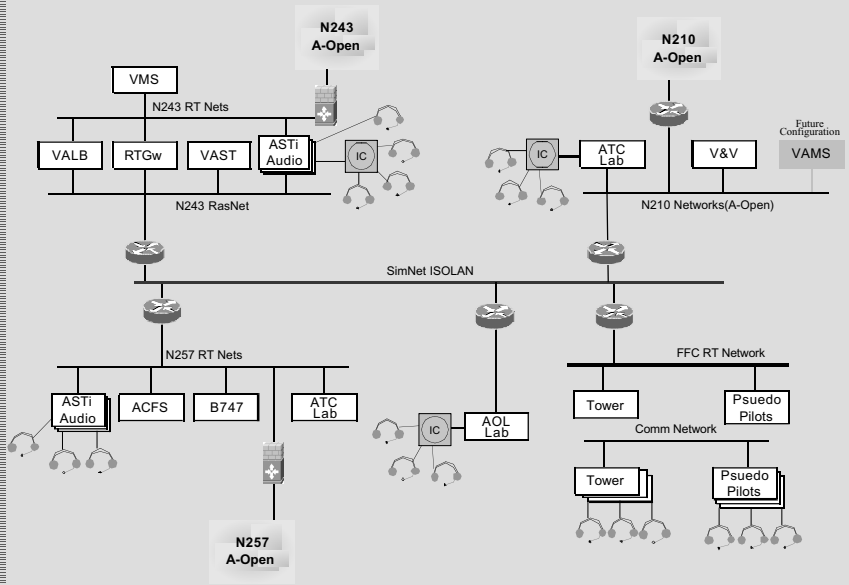
VAST RT

Current Facility Integration



VAST RT

Future Network

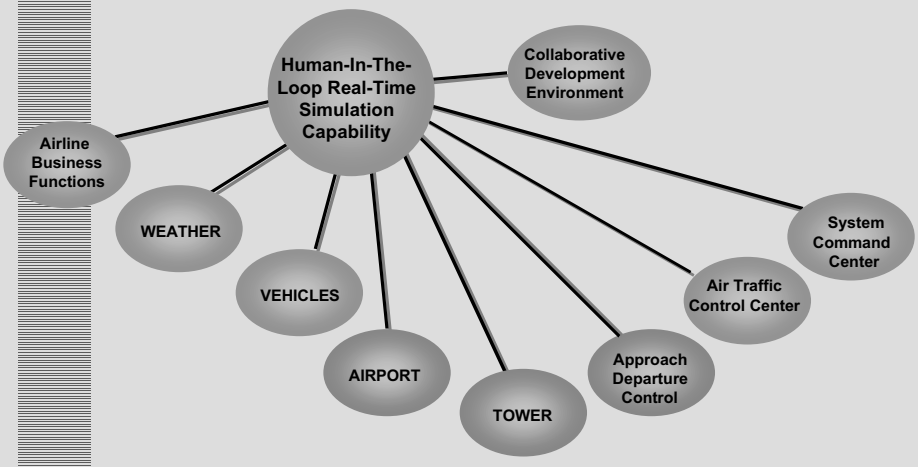


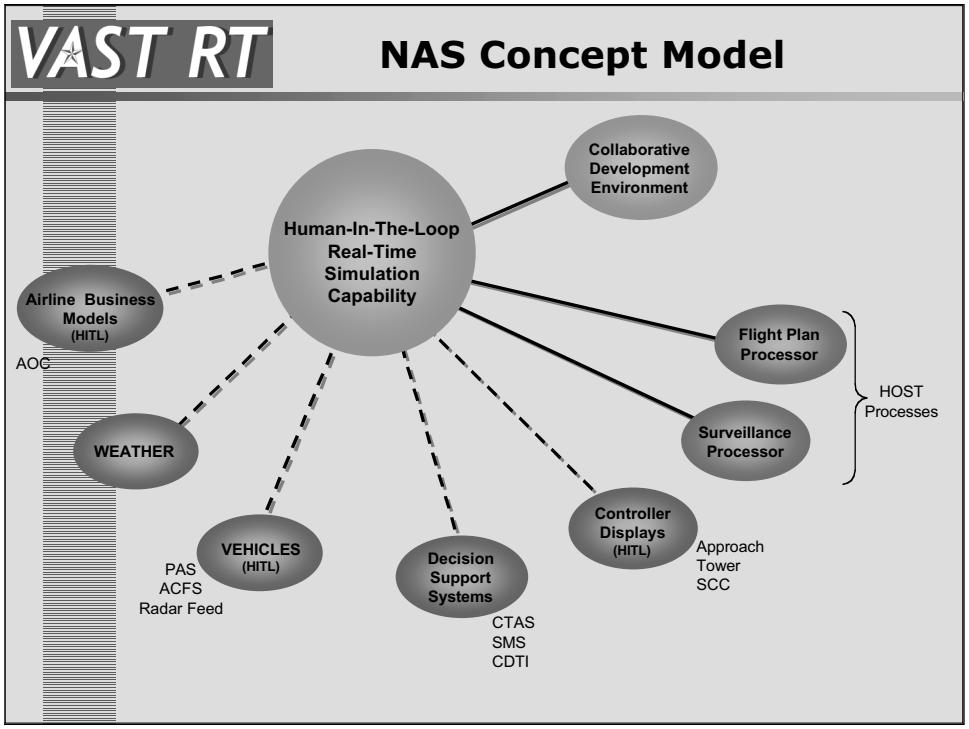
VAST RT

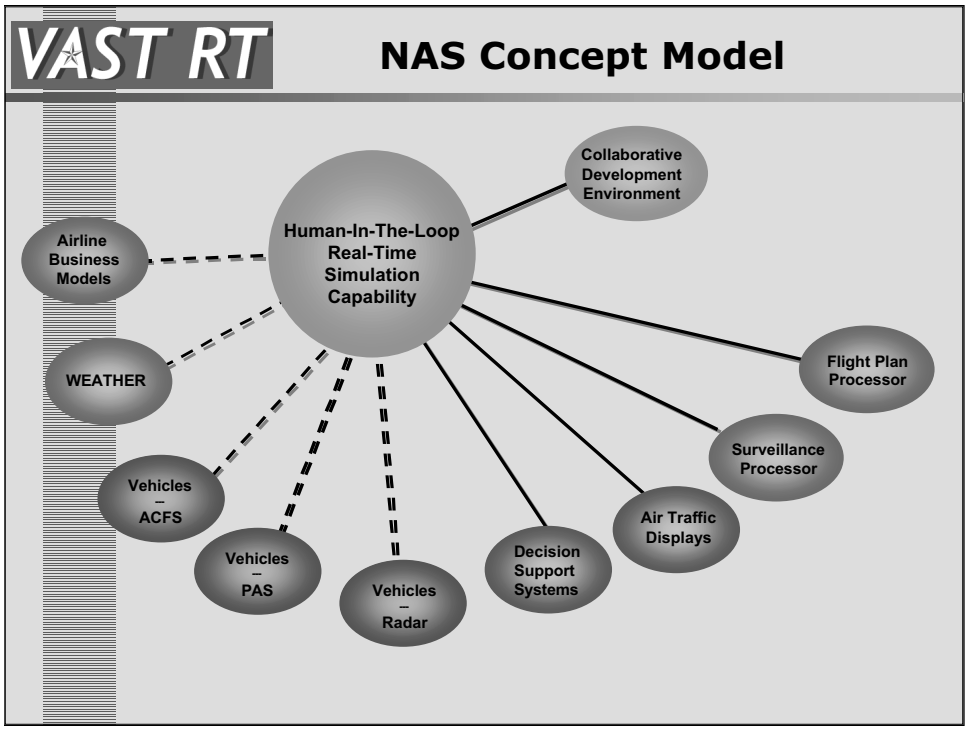
VAST Real-Time Simulation Models

VAST RT

VAST-RT CONCEPT




VAST RT
NAS Concept Model
Collaborative Development Environment
Human-In-The-Loop Real-Time Simulation Capability
Airline Business Models (HITL)
AOC
Flight Plan Processor
HOST Processes
Surveillance Processor
WEATHER
Controller Displays (HITL)
Approach
Tower
SCC
VEHICLES (HITL)
PAS
ACFS
Radar Feed
Decision Support Systems
CTAS
SMS
CDTI


VAST RT
NAS Concept Model
Collaborative Development Environment
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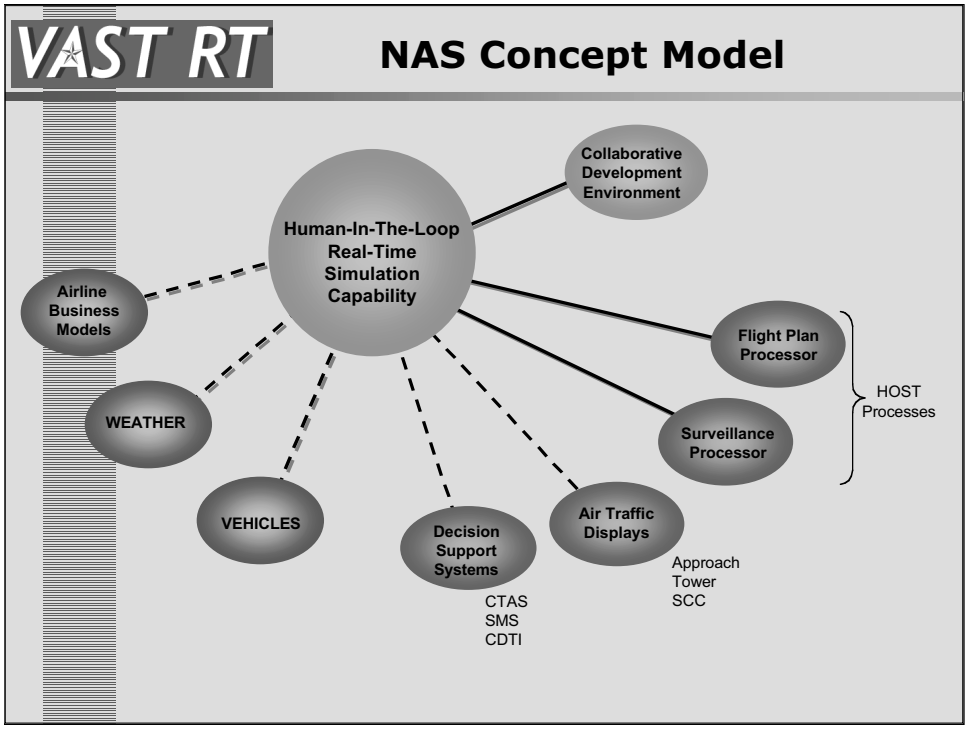
Airline Business Models
WEATHER
Flight Plan Processor
Surveillance Processor
Vehicles – ACFS
Air Traffic Displays
Vehicles – PAS
Decision Support Systems
Vehicles – Radar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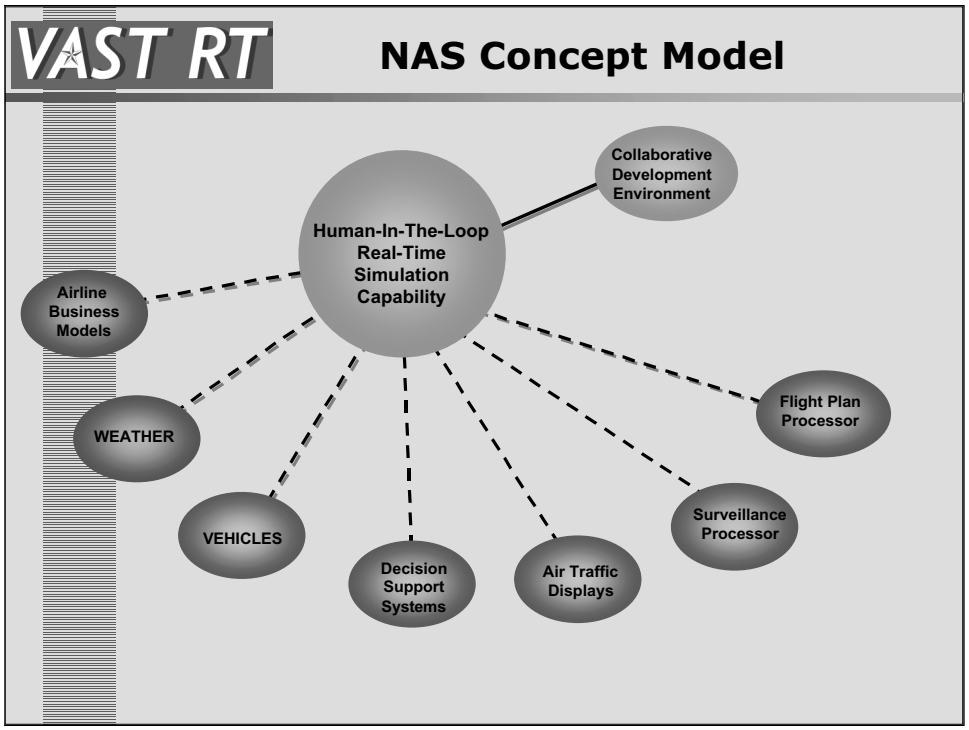
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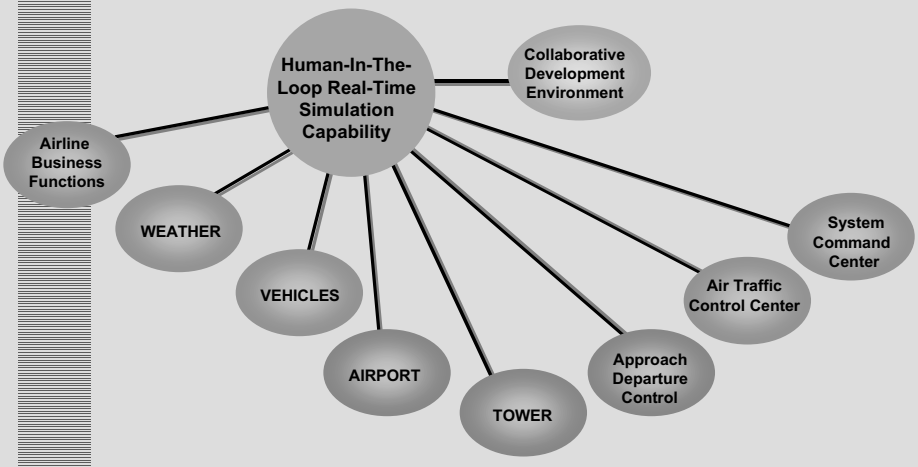
VAST RT

VAST Real-Time Collaborative Development Environment

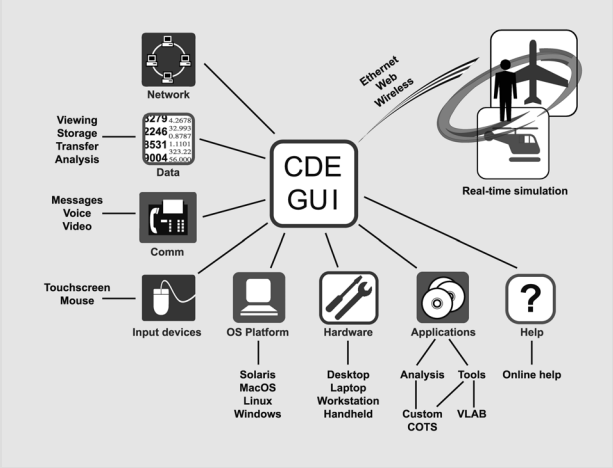
VAST RT

SYSTEM ARCHITECTURE



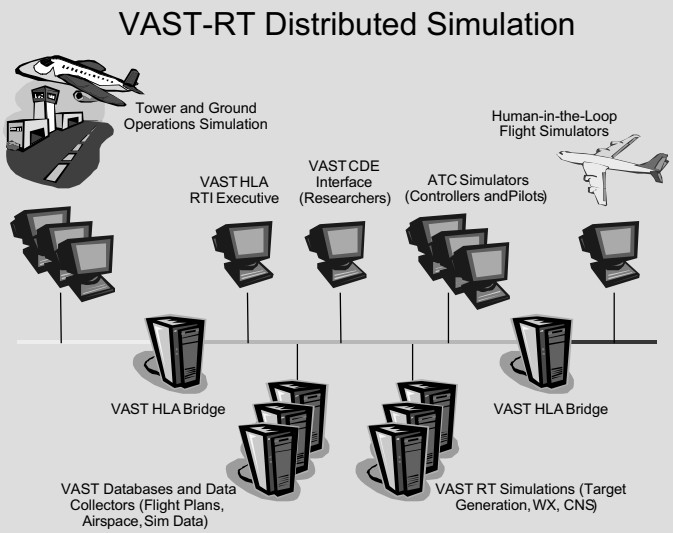
VAST RT

Concept - CDE Vision



VAST RT

WRAP UP



Human and Team Modeling

Roger Remington
NASA Ames Research Center
VAMS TIM #2

Outline

Goals and requirements
Approach to human performance modeling
Milestones accomplished in FY'02
Outyear milestones
Questions and comments

Goals

Provide models of human performance that can be used in fast-time simulation evaluations of airspace concepts

Provide software agents for use in real-time simulations

Develop a computational architecture that supports rapid configurability, promoting the reuse of software modules across scenarios

What Modeling & Simulation Needs to Address

Existing ATM Framework

- Aircraft
- ATC
- System Command Center
- Airline Operations Center
- System operations
  - Capacity, delays
  - Sector & route structures
  - Planning
  - Equipage
  - Constraints

Innovations

- CNS Technology
- Broader access to information
- Distributed management
- Flexibility
- Automation

Impacts

- Safety
- Security
- Environment

Requirements for Human and Team Modeling

Model operationally relevant agents and functions

- Aircrews
- Air traffic controllers
- Dispatchers

Make operationally useful predictions

- System throughput (capacity)
- Error consequences and recovery
- Sensitivity to deviations from nominal human performance

Simulate performance in external simulation environments

- HLA compatible modeling toolkit
- Software agents for real-time

Model team performance characteristics

- Distributed decision making
- Communications
- Characteristics of supervisory control involving other humans or highly automated systems

Concepts

System Level Concepts

- All Weather Maximum Capacity Concept
- Massive Point-to-Point (PTP) & On-Demand Air Transportation System Investigation
- Air Transportation System Capacity-Increasing Concepts Research Proposal
- Concepts for System-wide Optimization

Domain Specific Concepts

- Capacity Improvements Through Automated Surface Traffic Control (Surface)
- Surface Operation Automated Research (Surface)
- Centralized Terminal Operation Control (Terminal)
- Terminal Area Capacity Enhancement Concept (Terminal)
- Advanced Airspace Concept (Enroute)

Approach

Complex dynamic environments

Time Pressure: **Users must make timely inputs**

Multitasking: **Users juggle multiple tasks**

Predictability: **Similar patterns occur over time**

Unpredictability: **Interruptions occur**

Mixed-initiative: **Decision authority distributed, includes other users and automated systems**

Resource Allocation

A multi-tasking agent must allocate resources proactively and reactively

- Mechanisms for task suspension and recovery
- Mechanisms for parallel task execution subject to *resource constraints* and *logical dependencies*

These mechanisms are also important for HCI predictions that arise from the interleaving of primitive *cognitive*, *perceptual*, & *motor* acts

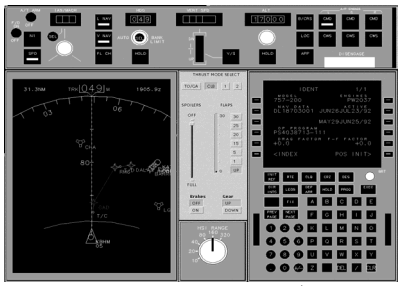
Motivations

Construct a modeling system that can make useful predictions about skilled operator behavior in complex dynamic environments

Make cognitive modeling more accessible to non-specialists, especially in the design phase

- Reduce model development time
- Simplified cognitive architecture
- Reusable packets of psychological theory that can attach to a standard task analysis (templates)
- Focus on routine, well-learned behavior

Usability Analysis



Route planning, entry, and modification using Flight Management System (FMS)

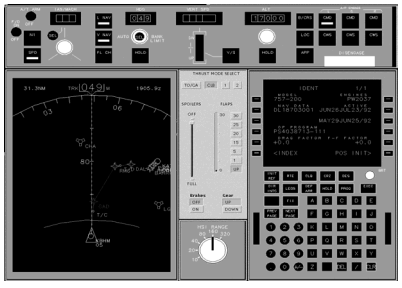
Situation Awareness

Knowledge of how to use

Anticipating FMS behavior

Routine Use

Usability Analysis



Skilled operator

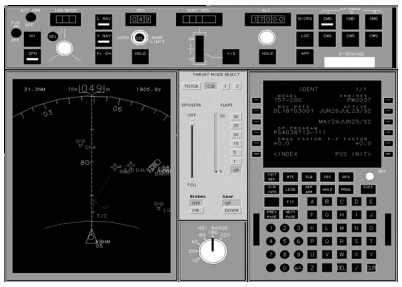
Knows what she wants to do

Knows how to do it

Is not confused about FMS state or behavior

How easy is the system to use?
- Time
- Effect on concurrent tasks

Usability Analysis



Modeling a skilled user in routine interaction

- Casual Observation
- Expert Consultants
- Human Factors Guidelines & Handbooks
- Informal Usability Testing
- Part-Task Experiments
- Full-Mission Simulation

Apex and CPM-GOMS

Apex

Computational Architecture for Human Performance Modeling
- Task Representation Language
- Human Resources
- Resource Scheduler

Software System Implemented in Lisp

No built-in theory of Human Resource Interaction

CPM-GOMS

Methodology for Human Performance Modeling
- Task Analysis Method (Goals, Operators, Methods, Selection)

No Software Implementation

No automatic resource scheduling

Theory of Human Resources (Cognitive, Perceptual, Motor)

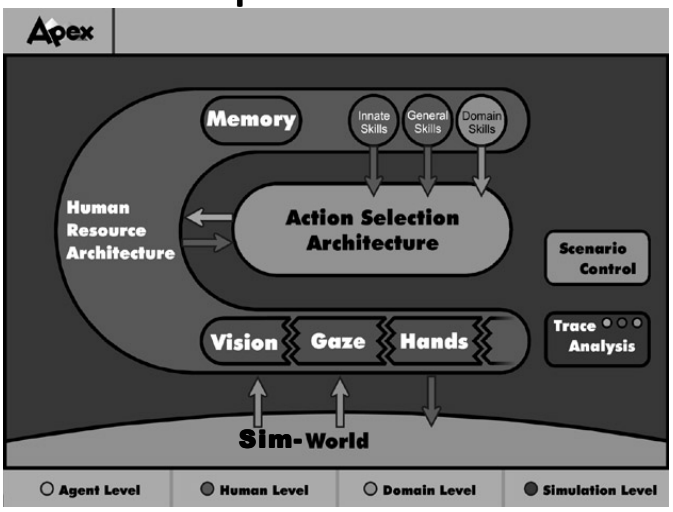
Apex approach

Apex simulates an agent planning and scheduling its limited resources to accomplish multiple task goals

Knowledge is represented as procedures

It's intended to be a flexible architecture that allows the modeler to implement a theory that specifies the constraints on parallel execution of procedures

The Apex Architecture



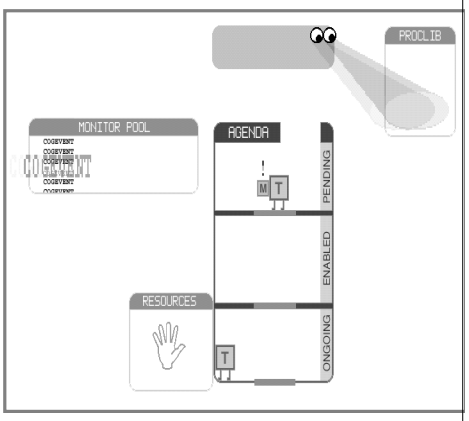
Task (Goal) Decomposition

Action Selection Architecture

Reactive planner
- Sketchy plans
- Hierarchical task decomposition
- Multitasking (Interruption)

Maximizes parallel processing
- Resource constraints
- Data dependencies

A Language for representing domain and human models
- Procedure Definition Language (PDL)



GOMS

GOALS
OPERATORS
METHODS
SELECTION

GOMS Components

Task Analysis

- **Goals**: Tasks decompose into nested hierarchy of goals and subgoals
- **Operators**: Hierarchy terminates in operators, whose actions cause transitions between states
- **Methods**: Sequences of operators executed to accomplish a set of subgoals
- **Selection Rules**: Rules that determine which method to use

Performance Computation

- Operator execution takes time
- Sequence of operators determines sequence of overt behaviors and task time

Varieties of GOMS

Keystroke-Level-Model (KLM)

- Flat task structure
- Mentally prepare coupled with primitive

Card-Moran-Newell GOMS (CMN-GOMS)

- Hierarchical goal decomposition
- Primitive operators in task domain (e.g. move mouse)

Cognitive-Perceptual-Motor (CPM-GOMS)

- Combines hierarchical goal decomposition with primitive CPM resources based on Model Human Processor

Goal of CPM-GOMS

Model the time for highly skilled people to accomplish tasks by using methods made up of elementary Cognitive, Perceptual, and Motor operators

Create cognitively-plausible, reusable "templates" that capture the parallelism and constraints in these methods

Integrate templates into a model that allows predictions to flow from a CMN-GOMS task hierarchy

- Shield the analyst from the complexity of templates
- Keep the analyst in the task domain

"Highly Skilled"

KLM and CMN-GOMS predict human behavior well

- When the user knows the procedures of a domain well and is presented with a new task
- When operators can be assumed to work sequentially

CPM-GOMS is needed

- When task becomes so routine that users perform activities in parallel to achieve faster execution time
- Examples in the lab:
  - Card, Moran & Newell, 1983, Chapter 8, Section 4.-- Text editing
  - Baskin & John, 1998 -- CAD
  - John, et. al., 2002 -- ATM
- Example in the field
  - Gray, et. al., 1993 -- Project Ernestine: telephone operator

Project Ernestine

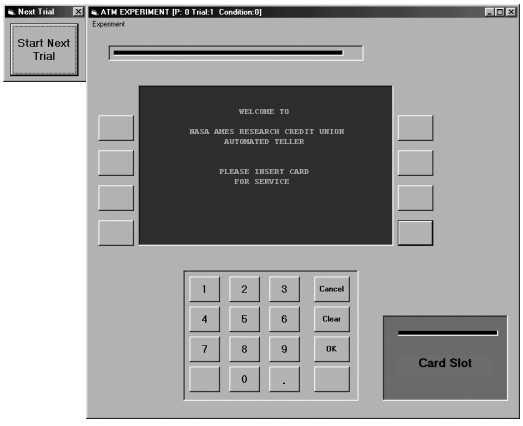
Gray, John, & Atwood (1993)

CPM-GOMS: Perhaps the most successful HCI technique.

Project Ernestine: application of CPM-GOMS saved Bell Atlantic millions of dollars per year

Bell Atlantic

ATM Study

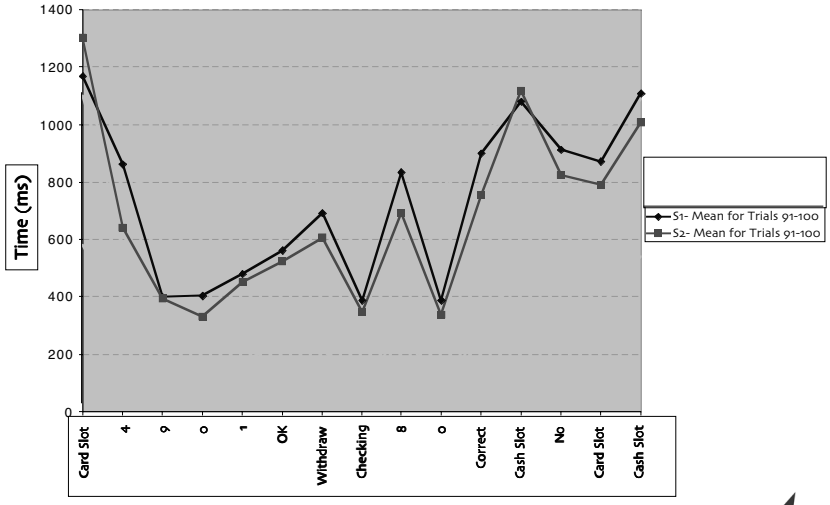


- 2 subjects
- 200 trials each

Steps:

Insert card (click card slot)
Enter PIN (4901)
Press OK
Select transaction type (withdraw)
Select account (checking)
Enter amount (80)
Press if correct/not correct? (correct)
Take cash (click cash slot)
Other Transaction (no)
Take card (click card slot)
Take receipt (click cash slot)

Subject Move-and-Click Times



Modeling with Templates

Templates are models of small units of behavior at the level of Cognitive, Perceptual, and Motor resources

- Button pressing
- Mouse move-and-click
- Typing

Allow long sequences of behavior to be constructed from small unit tasks

Allow generality across task domains

Templates for Moving and Clicking Mice

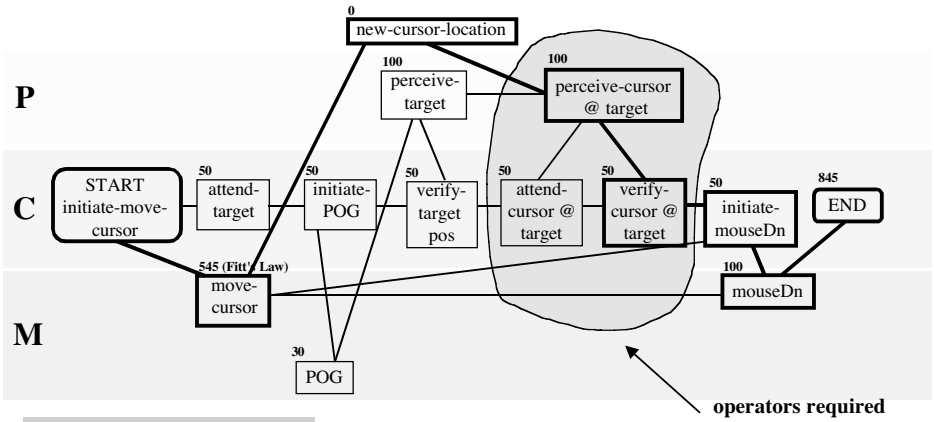
Gray & Boehm-Davis (2001)

Identified distinct micro-strategies that arise with practice in repetitive perceptual-motor tasks

Developed templates that model mouse move-and-click micro-strategies

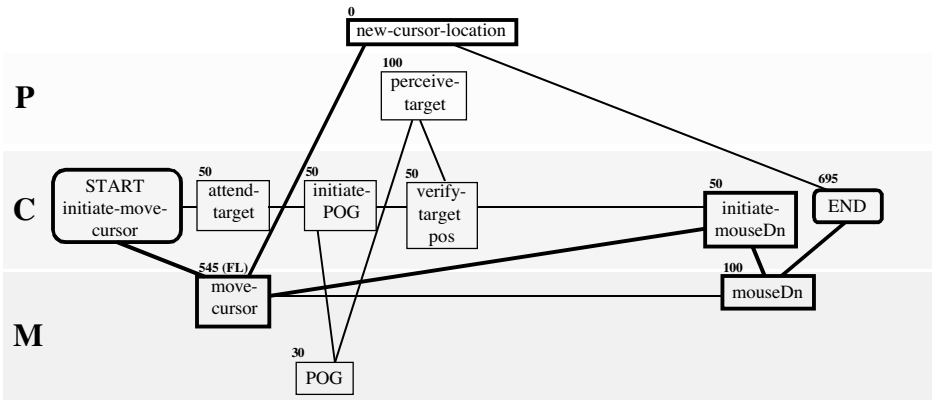
- Slow mouse-move-and-click
- Fast mouse-move-and-click

SLOW MOVE-CLICK



- from *Gray and Boehm-Davis (2001)*

FAST MOVE-CLICK



- from *Gray and Boehm-Davis (2001)*

Constructing sequences of behavior from templates

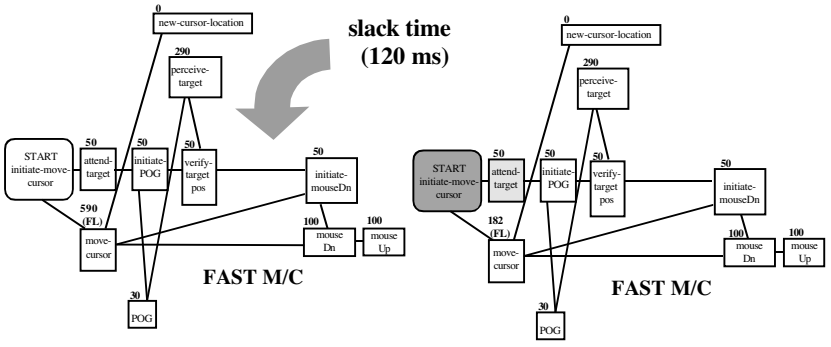
Can't just stick templates end-to-end

- Overestimates the time
- Fails to capture parallelism in human behavior

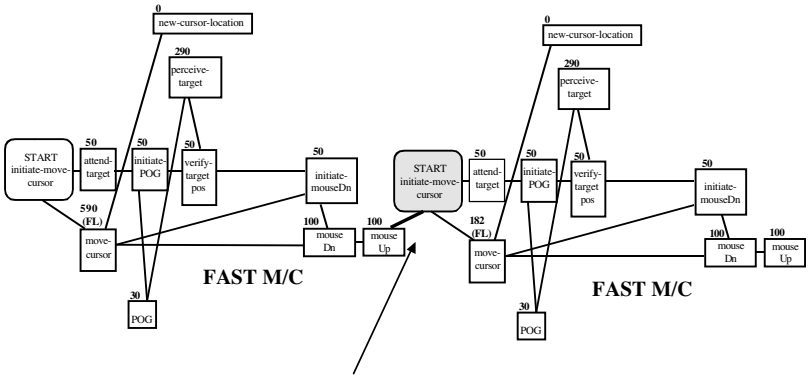
Interleave templates

- Execute **Cognitive** operators from a later template in the slack time in an active template
- Must consider logical and resource dependencies
- Interleaving embodies a theory of human parallel processing

Interleaving Templates

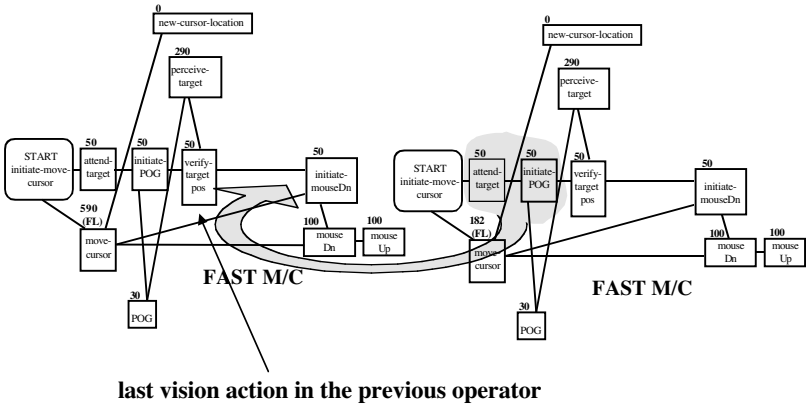


Interleaving Templates

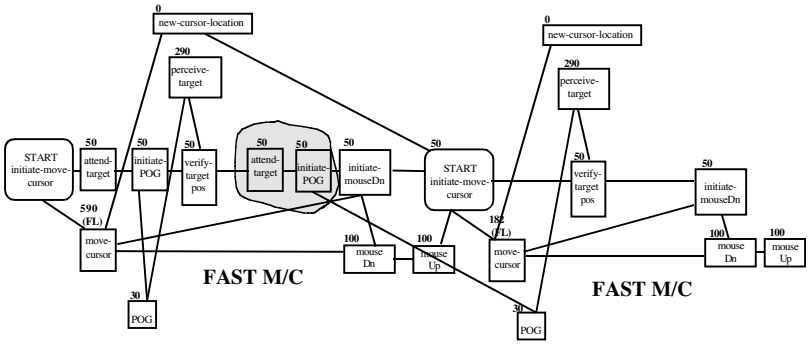


initiate move cursor cannot precede the last motor action with the same hand in the previous operator

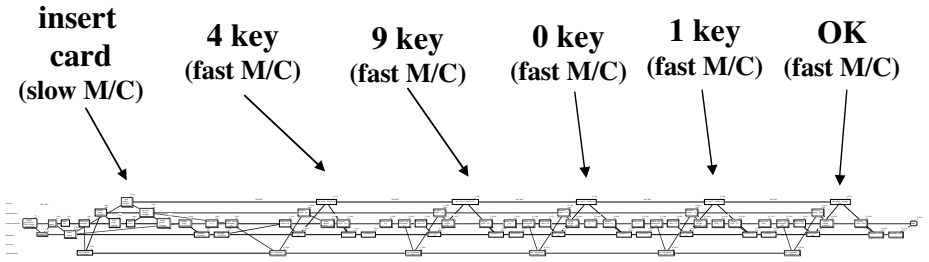
Interleaving Templates



Interleaving Templates



A CPM-GOMS Model of a Portion of the ATM Task



This part of the model describes ~ 5 sec of behavior, and it took over 6 hours

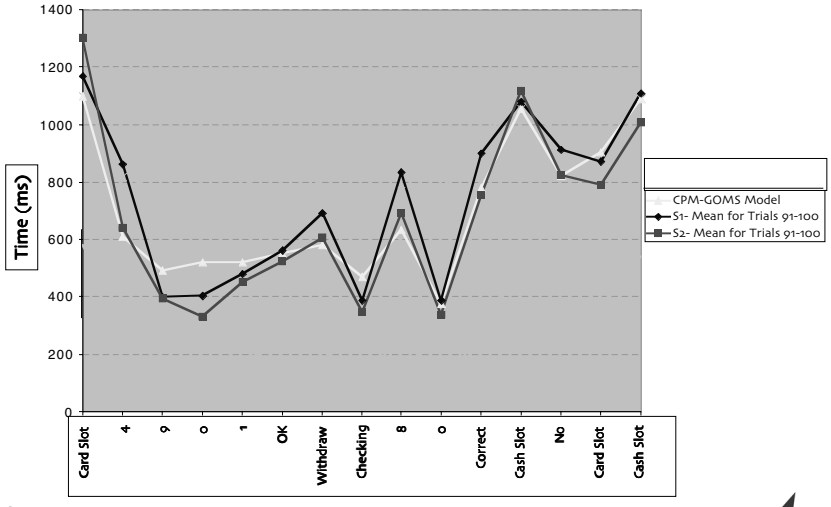
Expert Rules for Interleaving

In-depth interviews and discussions with two CPM-GOMS experts (Alonso Vera and Bonnie John)

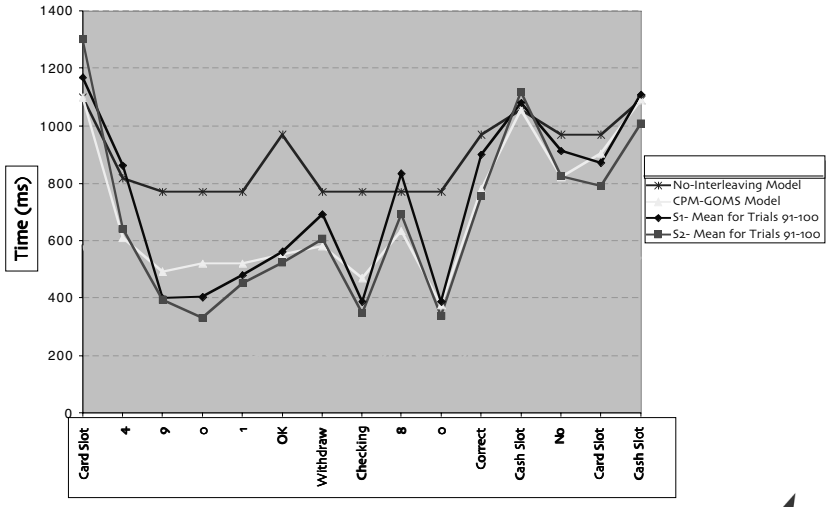
At each boundary between templates, for each operator, ask…

1. Is the candidate operator a cognitive initiate action for resource X? If yes,
2. Is there enough slack time at the end of the first template to allow interleaving? If so,
3. Are there any logical dependencies preventing the candidate cognitive operator from interleaving? If not,
4. Have all operators of the same type in the previous template that use X completed? If yes,
5. Interleave the candidate operator and GOTO 1.

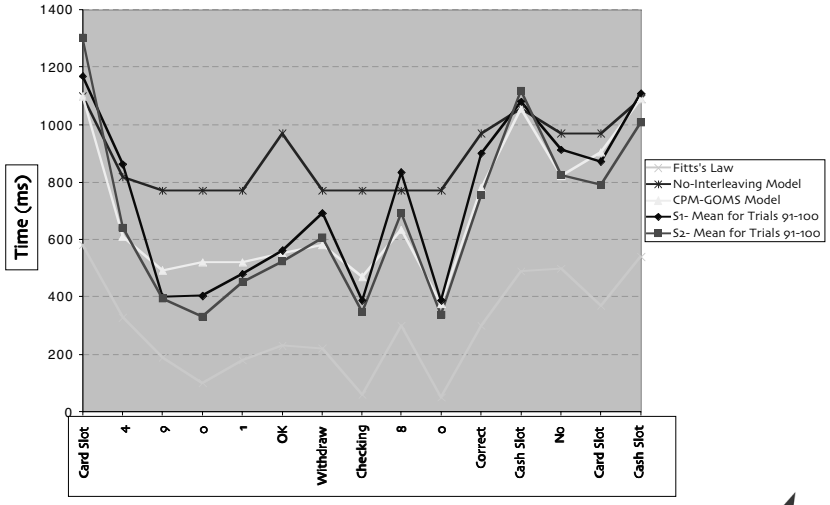
Human/Model Comparisons: CPM-GOMS model built with Apex



Human/Model Comparisons: No Interweaving



Human/Model Comparisons: Fitts's Law only



Significance

Ability to model large-scale, dynamic environments

- Automated resource scheduling (template interleaving) makes it feasible to tackle complex environments
- Templates provide a pre-packaged theory module
- Templates constitute a library of reusable software modules

Capability to realize the latent potential of CPM-GOMS for providing generic level of modeling human-system interaction

Capability of going from theories of information processing to macroscopic world of flight deck or air traffic control

Website

ftp://eos.arc.nasa.gov/outgoing/apex/apex

- Latest versions of Apex (Apex 2.2b4)
- Macintosh and PC
- Some of the worlds
- Documentation
- Instructions on downloading and running
- Patches
- We are trying to update it regularly to keep it current

FY'02 Milestones

Develop requirements for a cognitive modeling architecture that supports rapid reconfiguration of human performance models

- Vera, A., Remington, R., Matessa, M., John, B.E., Freed, M.A. (2002). Automating human-performance modeling at the millisecond level. *Journal of Human-Computer Interaction* (submitted)
- John, B., Vera, A., Matessa, M., Freed, M., & Remington, R.W. (2002). Automating CPM-GOMS. Annual meeting of ACM SigCHI, April 22-25, Minneapolis, MN.
- Freed, M. & **Remington, R.W.** (2000). Making human-machine system simulation a practical engineering tool: An Apex overview. In *Proceedings of the 2000 International Conference on Cognitive Modeling*. Groningen, Holland.

Develop a computational architecture that can interact with the external simulation environments specified for VAMS system builds

Outyear milestones

- Demonstrate interoperability with external software or simulation environment (12/02)
- Provide preliminary models of controller and aircrew for Build 1 that model delays introduced by human operators (5/03)
- Investigate and model human multitasking characteristics relevant to aircrew, controller, and dispatch operations (9/03)
- Provide models of controller, aircrew, and dispatch that extend preliminary models by including multitasking applied to specific concepts (9/04)
- Investigate human factors issues associated with supervisory control in teams for concepts involving other decision agents, including humans and automation (e.g., super-sector) (9/04)
- Incorporate aircrew, controller, and dispatcher models into modeling toolbox (9/05)

VAST
Communications, Navigation, and Surveillance Modeling

Steve Mainger
Acting Manager
NASA Glenn Research Center
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August 28, 2002

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OBJECTIVES

- **Develop requirements for CNS modeling that supports evaluation of advanced airspace concepts**
  - Identify and categorize CNS modeling and simulation capabilities and needs
  - Identify CNS modeling approach
- **Develop communication, navigation and surveillance models for today's system, technologies currently being considered within the FAA's OEP, and technologies being considered for the future**
  - Develop and demonstrate standard communications traffic model for assessing CNS model elements and architectures
  - Integrate CNS modeling activities into Airspace Modeling Toolbox

CNS Modeling

STATUS

- **Identification and categorize of existing CNS capabilities for modeling and simulation**
  - Exploration for sources of model or simulation needed - Draft study submitted.
- **Identify CNS modeling and simulation needs**
  - Basis of this lays in existing AATT and DAG-TM CNS requirements work
- **CNS modeling approach**
  - Definition being worked.
- **Develop and demonstrate standard communications traffic model for assessing CNS model elements and architectures**
  - FASTE-CNS development to provide communications, navigation or surveillance traffic profiles - Critical Design Review complete(8/23/02).
- **Integrate CNS modeling activities into Airspace Modeling Toolbox**
  - Definition being worked.

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Today's CNS Infrastructure

- **Analog communications links**
  - **Voice - DSB-AM, 25kHz bandwidth**
  - **ACARS - character-oriented data messaging, 25kHz**
- **Digital communication links**
  - **Oceanic SATCOM**
- **Navigation aids**
  - **VOR; ILS**
  - **Loran**
  - **GPS**
- **Surveillance radar**
  - **Primary radar**
  - **Secondary radar - mode A, C and S**
  - **TCAS (collision avoidance transponder)**

Emerging CNS Infrastructure

- **Analog communications links**
  - **Voice - DSB-AM, 8.33kHz bandwidth**
- **Digital communication links**
  - **Voice - VDL Mode 3**
  - **Bit-oriented data - VDL Mode 2, 3, & 4, UAT, 1090ES, SATCOM**
  - **Communication networks - ATN**
- **Navigation aids**
  - **GPS with WAAS and LAAS**
- **Surveillance radar**
  - **ADS-B/TIS-B, UAT, 1090ES**

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What CNS "components" need to be modeled?

- **Communications:**
  - Voice - 25kHz BW and 8.33kHz BW
  - ACARS
  - Data links - VDL2; VDL3; UAT; 1090ES; SATCOM
- **Navigation:**
  - VOR
  - ILS
  - GPS w/WAAS & LAAS
- **Surveillance:**
  - Primary Radar
  - Mode S, C or A
  - TCAS
  - ADS-B/TIS-B; UAT; 1090ES

Future Aeronautical Subnetwork Traffic Emulator for Communications, Navigation & Surveillance

Computer Networks & Software, Inc.
Chris Wargo

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CNS Modeling
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Project Summary

- Title: Future Aeronautical Subnetwork Traffic Emulator for Communications, Navigation & Surveillance (FASTE - CNS)
- Project: Develop a dynamic communications estimating tool that is accessible via the Internet. FASTE-CNS supports collaborative research by providing a means to define and assess the communications traffic loading associated with aeronautical related applications.
- Plan/Deliverables:
  - Phase I. System Design/Software Development (Nov 02)
    - System Specification & System Design Drawings & Reviews
    - Software Requirements & Detailed Design Document & Review
    - Software Development, Integration & Test
  - Phase II. Hosting & Evaluation (Planned for 2nd Qtr FY03)
- Today's Status: Critical Design Review Completed

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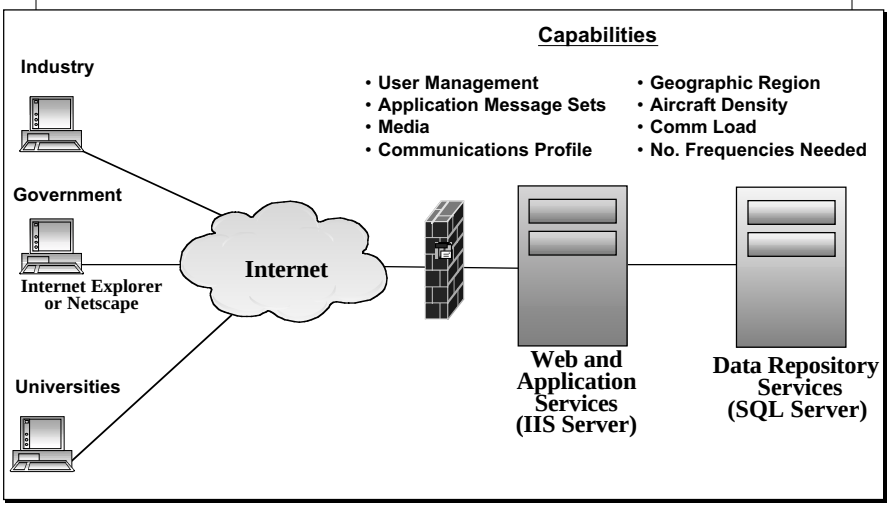
FASTE-CNS System Architecture



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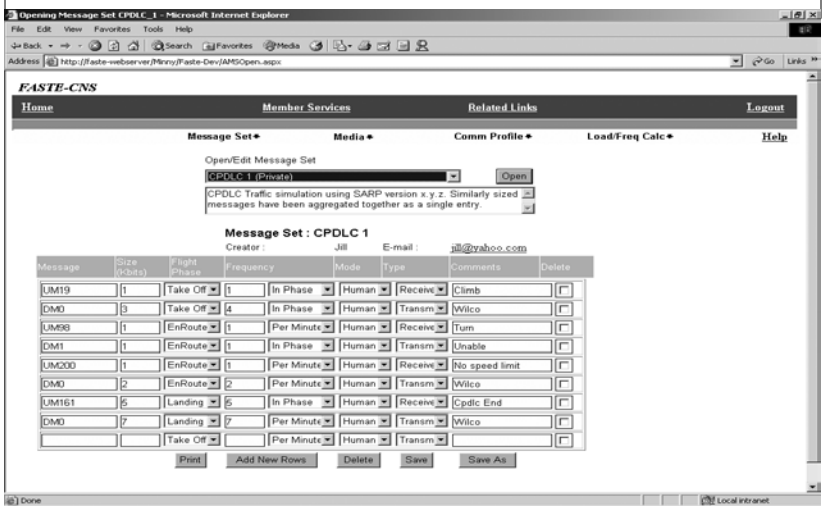
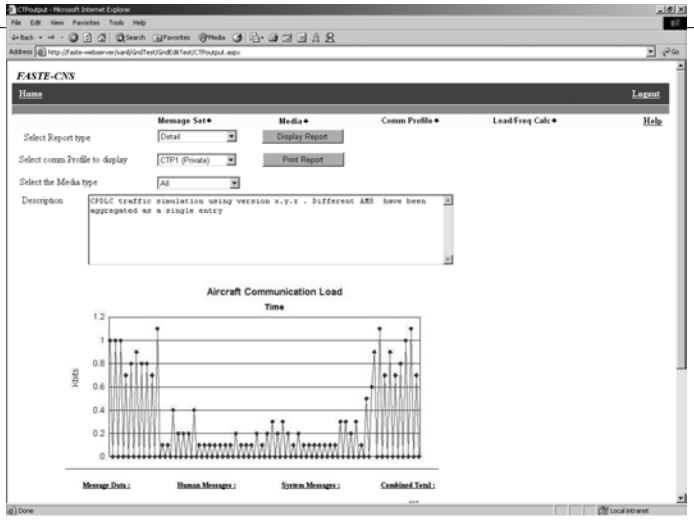
Features

- Each application profile may be allocated to different communication subnets.
- Each researcher may keep a number of application profiles on file for later use as well as have access to sets of typical applications profiles.
- Loading displayed for a typical flight profile.
- Airspace model depicts number of aircraft within selected airspace.
- Aggregate assessment of throughput requirements calculated to allow assessment of resources for various subnetworks.
- High-level performance models for the communications subnetworks available.
- Means to collaborate between researches provided.

Define Application Message Set

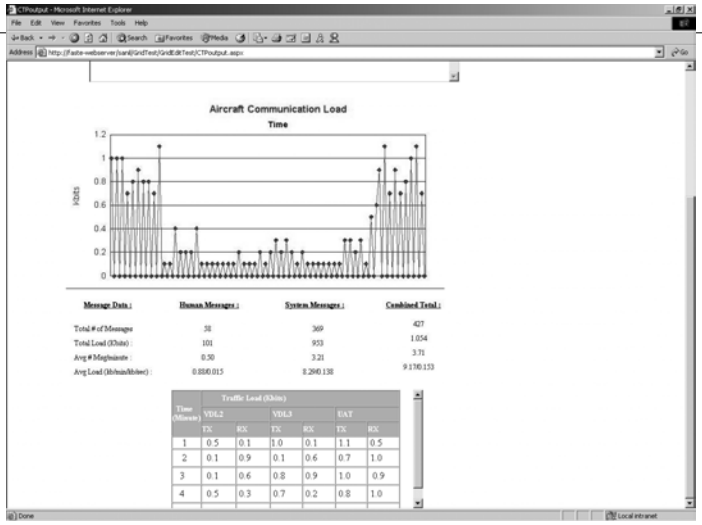


Comm Profile Report …



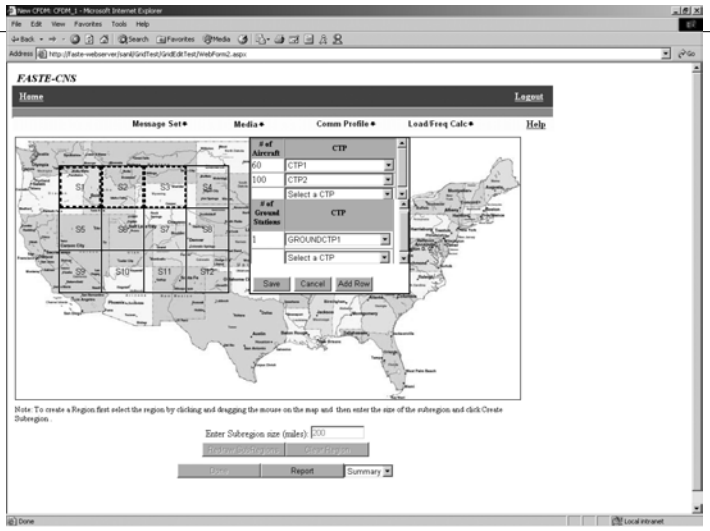
CNS Modeling

…Comm Profile Report



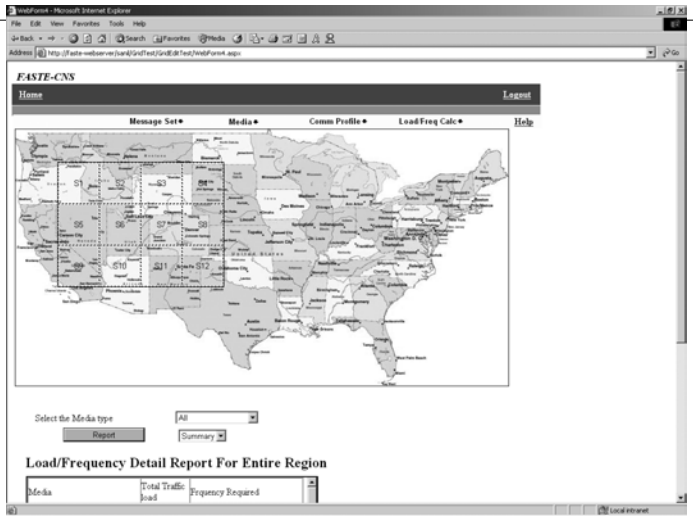
CNS Modeling

Aircraft/Comm Profiles



CNS Modeling

Load/Frequency Report …



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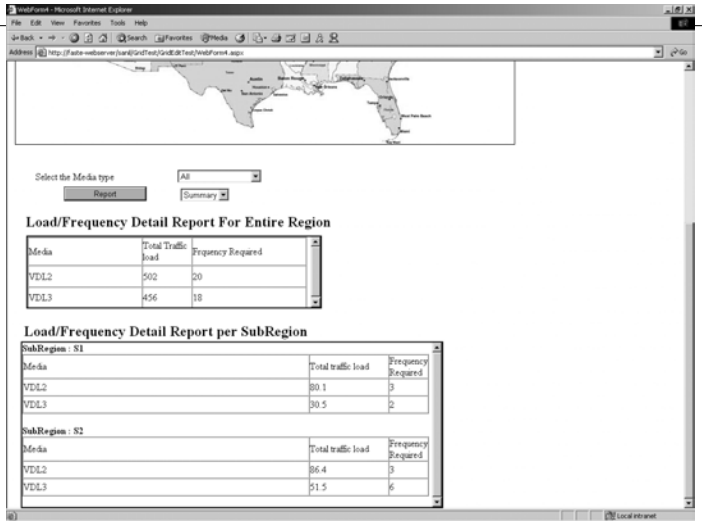
… Load/Frequency Report



Communication Traffic Generator

Future Aeronautical Subnetwork Traffic Emulator for CNS (FASTE-CNS)

- **Can be viewed as a configuration tool to set-up and define the tests that other CNS models would perform**
- **Could export configuration data using HLA/RTI**
- **Could import route models and apply communications traffic loading results from the route concepts developed ACES**
- **Potential web access mechanism to the Airspace Modeling Toolkit.**

Modeling Tools

OPNET Technologies

- **Large body of GRC research already done using this modeling software**
- **Application supports HLA designs/implementation.**

MATLAB

Issues of Model Realism

In discussing realism of models or simulations, we use two basic terms—Fidelity and Resolution.

- **Fidelity is the degree to which aspects of the real world are represented in modeling and simulation. Fidelity is a measure of how the model or simulation acts. *Does it act like the real thing?***
- **Resolution is the degree to which physical (appearance) aspects of the real world would be represented. Resolution is a measure of how the model or simulation looks. *Does it look like the real thing?***

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Issues of Model Accuracy

- **How do you know if it is providing an accurate representation of reality?**
- **Verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. It answers the question, *"Did we build it correctly?"***
- **Validation is the process of determining the manner and degree to which a model is a accurate representation of the real-world from the perspective of the intended uses of the model, and of establishing the level of confidence that should be placed on this assessment. It answers the question, *"Did we build the right thing?"***
- **Accreditation is the formal certification that a model or simulation is acceptable to be used for a specific purpose. A recognized subject matter expert in the field can accomplish accreditation. Accreditation answers the question, *"Does it meet my needs?"***

Next Steps

- **Develop CNS Specifications and Requirements** – the CNS work under AATT and DAG-TM is providing direction for these (& other) critical parameters:
  - Message Integrity; Transit Delay (Latency); Precedence
  - Error bands; Position Accuracy; Update rates
  - Process all events vs. an aggregation of events
- **Prepare External Interface Details and Specification**
- **Define the Appropriate Metrics**

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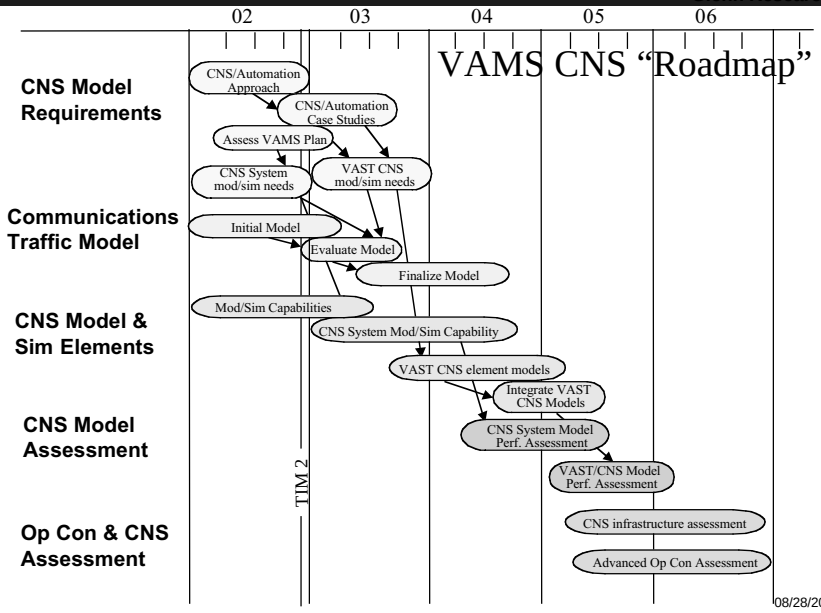

VAMS TIM #3

- Tentative dates January 14-16, 2003
- Concept sharing within VAMS community
- Self-evaluation scenario and metrics
- Common scenario and metric set
- Technology roadmaps
- Concept blending discussions
- Build-1 discussion
- EATN discussion

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14. ABSTRACT

A two-day NASA Virtual Airspace and Modeling Project (VAMS) Technical Interchange Meeting (TIM) was held at the NASA Ames Research Center in Mountain View, CA, on August 27 through August 28, 2002. The purpose of this meeting was to share information about the early modeling and simulation activities and how they relate to the advance air transportation system concepts sponsored by the VAMS Project. An overall goal of the VAMS Project is to develop validated, blended, robust and transition-able air transportation system concepts over the next five years that will achieve NASA's long-term Enterprise Aviation Capacity goals. This document describes the presentations at the TIM, their related questions and answers, and presents the TIM recommendations.

15. SUBJECT TERMS
Air traffic management, Air traffic control, Capacity

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